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Why it's all change for
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THE PERFECT HOME THEATER

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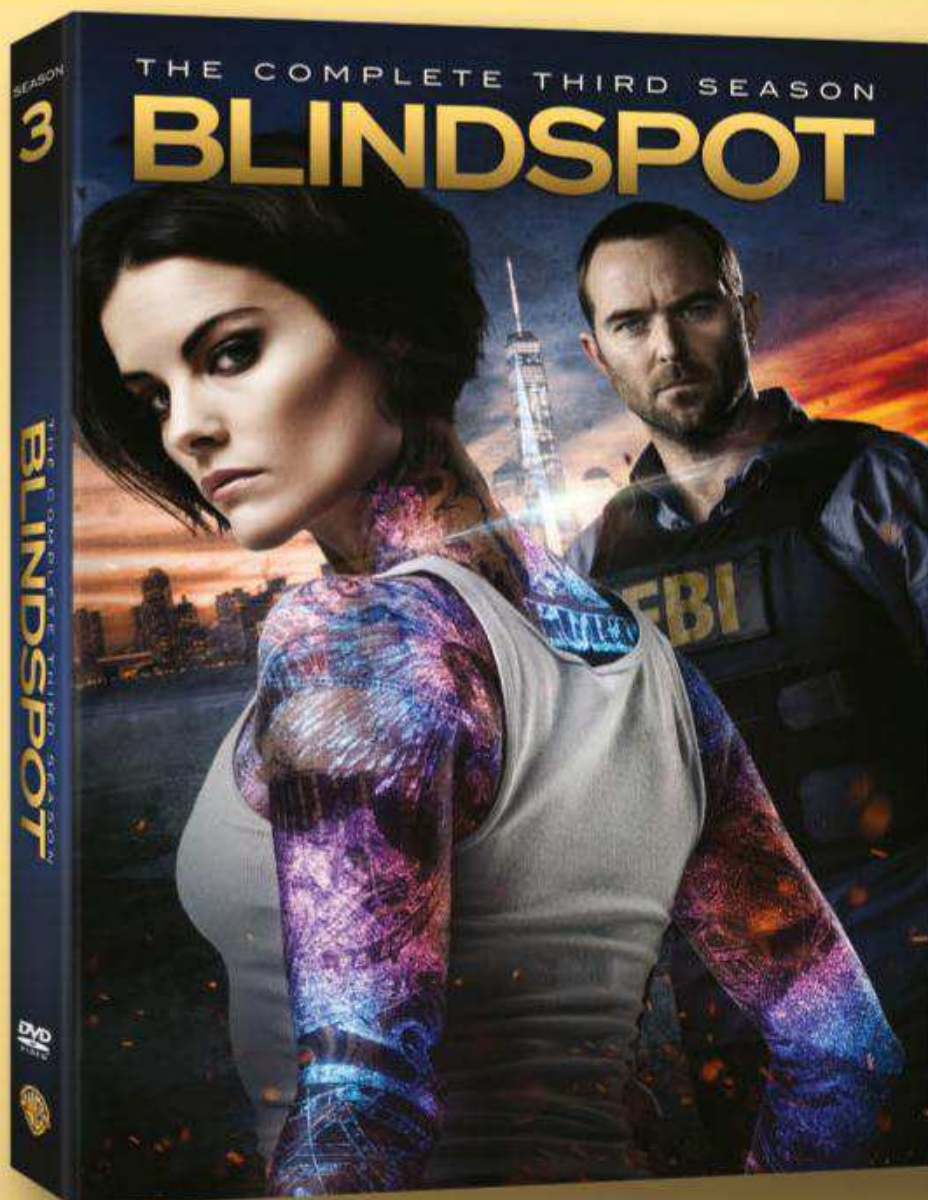
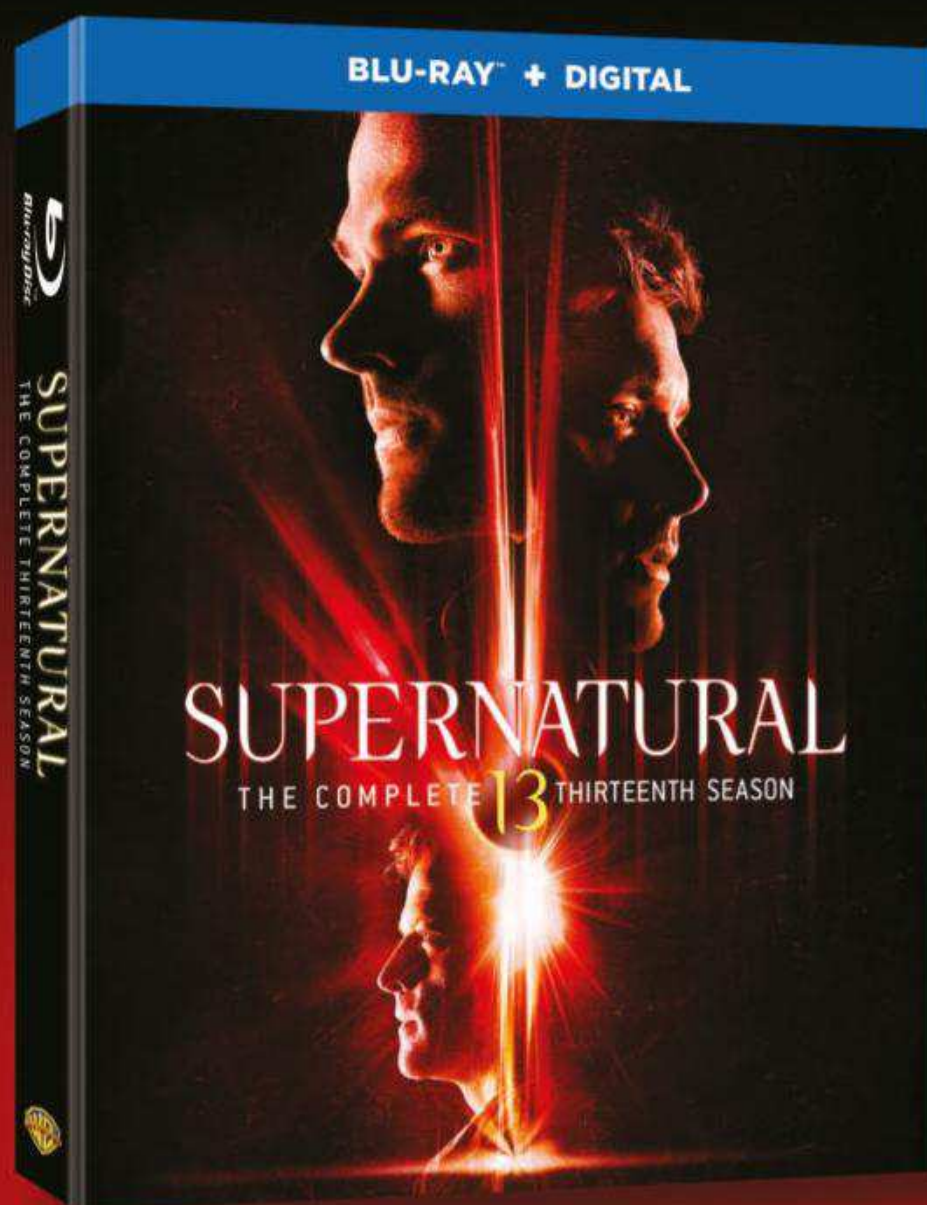
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Alan Dexter

THE CHANGING FACE OF ENTERTAINMENT

THE WAY WE CONSUME MEDIA has changed. According to the Digital Entertainment Group, which monitors disc sales in the US, physical media sales dropped by 14 percent in 2017, compounded by a 10 percent drop the year before. To put some cash on the table, last year we spent \$4.7bn on DVDs, Blu-rays, and Ultra HD 4K Blu-rays, but \$9.5bn on Netflix, HBO Go, and Amazon. It's clear what the future for entertainment looks like.

So, the sun is setting on owning a large pile of tapes, DVDs, and Blu-rays. Even if you haven't made the switch yet, you'll soon have to, unless you've got a particular reason to cling on to offline options (mostly down to a flaky Internet connection).

What does that mean for our media center PCs? It means they need to change to adapt to this brave new world. The good news is that by putting a fully functional PC under your big 4K HDR screen, you can do so much more than even the smartest of TVs. You can focus on what's important to you: a quality streaming machine, an offline media box, an HD audio center, or if your focus is on gaming, you can fit it with the best graphics cards around. Whatever works best for you.

Take a look at the options open to you on page 24, where we cover everything from the likes of the Raspberry Pi, Gigabyte Brix, and Apple TV, all the way up to our killer media monster, which does everything you'd want from a kick-ass PC, and looks absolutely incredible at the same time. We show you how to build this machine in our "Build It" spot

on page 70, and as ever, if you want to tweak it to your own needs, you can use this build as a starting point, and change it to suit your requirements.

This isn't the only build this issue, as we also take a look at what you need to wrestle with in order to build an audio workstation, on page 34. As with so many other activities, what was once the preserve of professional hardware can now be done far more affordably with the right PC, set up in the right way. We're here to show you how to get started.

In our other feature this month, we look at what the future holds for our graphics cards, and how the work in GPGPUs is becoming the defining factor. Starting on page 46, we take a look at the evolution of the GPU: How it went from a fixed-function gaming device to a full-fledged computing engine, powering everything from medical research to becoming the key component in developing artificial intelligence.

In other news, we've revamped the *Maximum PC* newsletter once again, and you can sign up to it by heading over to www.maximumpc.com.



Alan Dexter is Maximum PC's executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.

submit your questions to: comments@maximumpc.com

THE NEWS

AMD Piles On the Pressure

AMD's hectic release schedule continues; Intel wallows

THE GUYS AND GALS at AMD are busy bees. Not a month goes by without something interesting emerging. This month, we have some fleshing out of the mid-range Ryzen family. There have been "leaks" (the processor world does seem very prone to this) on four new Ryzens.

We have the Ryzen 5 2500X, a four-core, eight-thread chip, running at a base of 3.6GHz, with a boost of 4GHz. It's faster than the 1500X, but loses out on 8MB of L3 cache. Sitting under this is the Ryzen 3 2300X, a four-core, four-thread CPU, running at 3.5GHz, with a 4GHz boost.

We also have two low-power Ryzens due soon. The Ryzen 5 2600E, a six-core, 12-thread chip, with a base speed of 3.1GHz. Above this is the Ryzen 7 2700E, an eight-core, 16-thread chip, running along at 2.8GHz. Both these "E" models have a TDP of 45W, under half of the "X" versions, although clock speeds take a pummeling to achieve this; the 2700E is 900MHz slower than the 2700X.

There's nothing firm on the pricing yet, but expect the usual

competitive numbers. Less practical, but more interesting, is the imminent arrival of the new Threadrippers—we saw the pre-production samples at Computex. The Threadripper 2990X has 32 cores and 64 threads, and is expected to run at a base of 3GHz, with a boost of up to 4GHz. Below this sits the 2950X, with 24 cores and 48 threads. Prices are unconfirmed as yet, but expect around \$1,750 for the 2990X, undercutting Intel's finest i9s. Both are due to ship in August, and performance will be spectacular.

Intel has nothing ready to match this. The best we have is a refresh of the eighth-generation Coffee Lake S chips, due sometime soon; these ninth-generation chips will bump speeds here and there—100MHz on some base speeds, and up to 200MHz on turbo. They all feature model numbers starting with 9. We have the i5-9600K, 9600, 9500, and 9400, and the i3-9100 and 9000. The i5-9600K has the biggest speed hikes, gaining 100MHz on the



The huge Threadripper 2990X is going straight to the top of the HEDT market.

base clock—3.6 to 3.7GHz—and 200MHz on turbo, from 4.3 to 4.5GHz. There's nothing yet on the i7 or i9 versions; perhaps something more interesting is still to be revealed.

Meanwhile, in China, we have a new entrant in the world of x86 processors: Hygon. It's the result of a complicated licensing deal struck by AMD back in 2016, when the company needed the cash to fund its Ryzen development. In return for \$293 million and a slice of sales revenue, AMD sold its chip design. The Dhyana chips are based on AMD's Zen architecture, and are essentially EPYC chips in all but name. The deal precludes their sale outside China, where they are destined for server farms. This may have little impact now, but in time it will. This is a long-term strategic move by the Chinese, who hope to be

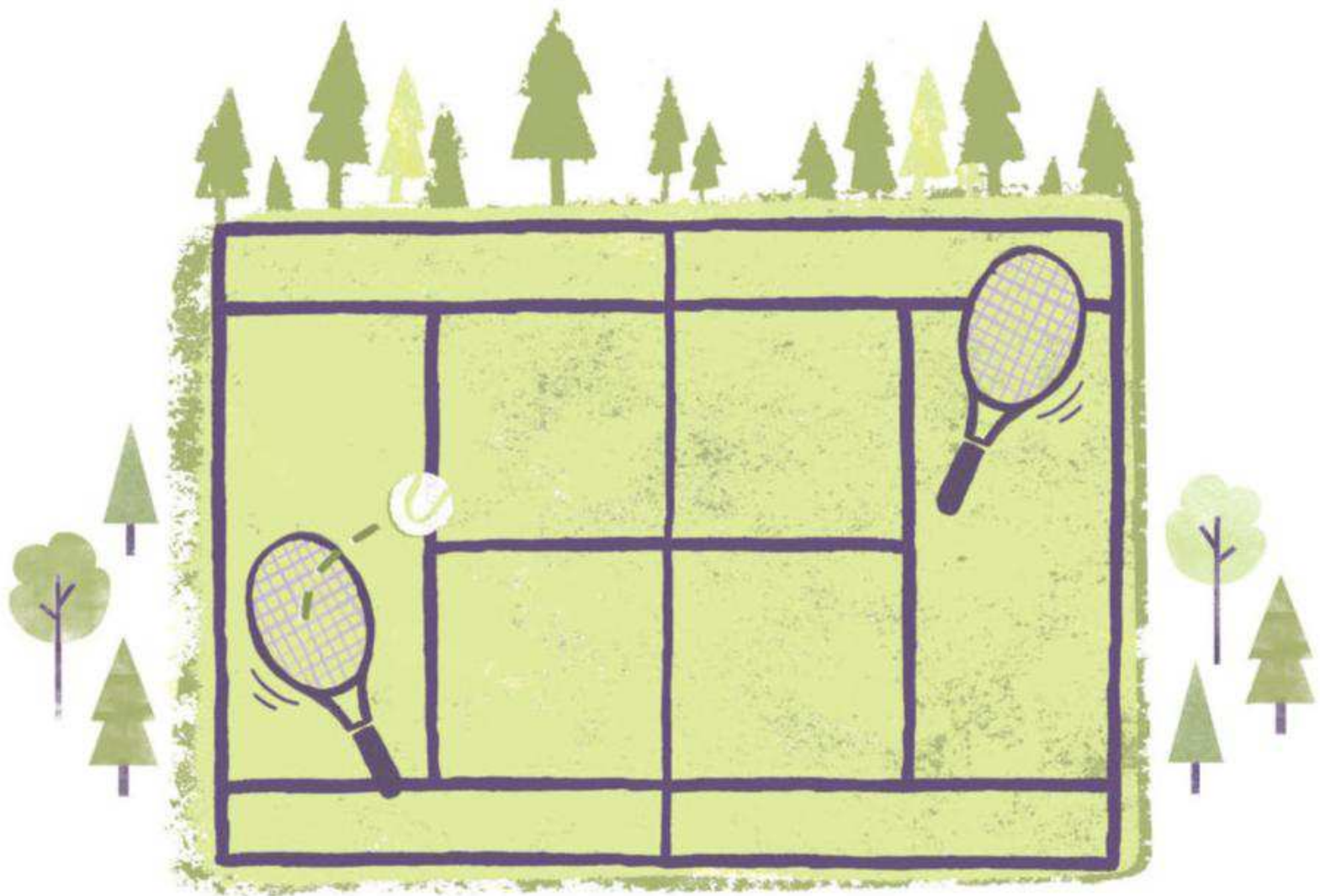
independent in silicon by 2025. It can't be good news for Intel either, as China's huge server market goes AMD-based.

When AMD launched Ryzen, we expected a robust response from Intel, but didn't expect to have to wait this long. The problem is Intel is moving to a 10nm process, and it's become a nightmare. Huge engineering problems mean yields are terrible, and have caused delay after delay. Currently, the company reckons on sometime in 2019 for volume production. A far cry from the original estimate of 2015. 10nm Cannon Lake chips are shipping; tiny numbers of i3-8121U parts so far. Until 10nm really comes on stream, all Intel can do is fiddle with its existing 14nm chips, trying to squeeze what it can out of them using optimizations. It looks as though AMD's timing has been rather fortuitous. **-CL**



The best we have from Intel is a refresh of the eighth-gen Coffee Lake S chips.

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BITCOIN CRASHES, AGAIN

Is reality catching up
with Bitcoin?

BITCOIN IS the poster child for cryptocurrencies—just before the end of last year, it topped out at \$19,783. At the time of writing, it stands at \$6,519, a 67 percent drop. Analysts have naturally looked around for causes for the latest crash.

Among the cited culprits is a report on the Bitfinex exchange by the University of Texas, which pointed to market manipulation of cryptocurrency Tether influencing Bitcoin's value. Algorithms uncovered an association between the Tether and Bitcoin spikes.

Also, last month Coinrail, a South Korean cryptocurrency exchange, was hacked, and \$40 million in various coins was spirited away. China's continuing clamp-down on fundraising through cryptocurrencies also worried others. Whatever the catalysts were, the drop points to a lack of confidence.

Some heavyweights of the financial world have passed comment. The Nobel Prize-winning economist and former chief economist of the World Bank, Joseph Stiglitz, said: "You cannot have a means of payment that is based on secrecy when you're trying to create a transparent banking system." He reckons cryptocurrencies attract nefarious activity, and "no government can allow that." The former chief of the IMF, Kenneth Rogoff, goes as far as to predict that "Bitcoin could easily be worth just \$100 in 10 years."

Others are less pessimistic, but even the optimistic panel of experts put together by the website Finder has halved its year-end estimate to around double the current value. Some are more bullish: Thomas Lee, head of research at Fundstrat Global Advisers, estimates a \$25,000 finish to the year.

Bitcoin isn't going away anytime yet, but even its most ardent adherents admit that it's due more cycles of extreme boom and bust. Stability is a long way off, and possibly requires regulation. One good thing has emerged from the dip, though: High-end graphics card prices have fallen. **-CL**

WIN 7 STILL LOVED WHICH IS SOMETHING OF A PROBLEM FOR WINDOWS 10

PEOPLE REALLY LIKE WINDOWS 7. The June figures from the analyst Net Applications show that Win 10 runs 40.4 percent of Windows PCs, while Win 7 has 47.3 percent. Win 10 managed to add a full point, but mostly at the expense of Win 8 and XP. If trends continue, parity is not expected until November. Other analysts differ. StarCounter, for example, is far more favorable to Win 10, putting it ahead. But all still show Win 7 in a strong position.

This is the problem: Support for Win 7 is due to be pulled in 18 months, by which time it's estimated that it will still be running on 30–36 percent of systems. When Windows XP had its plug pulled, it was running on 29 percent, and there was a good deal of unease then. There is no sign of a compromise yet, but like XP before it, there has to be. Ending security updates with these numbers would be insane. In the meantime, we can expect enthusiastic efforts to get us to upgrade; let's hope without too much trickery and pushing. **-CL**



ARE OUR GAMES SPYING ON US?

Red Shell tracker sneaks
into top titles



DO YOU EXPECT your games to send marketing information gathered from your online activity to a third party? Of course not. So when gamers found that the "spyware" Red Shell was bundled with their Steam games, there was an online uproar. The list of titles featuring the unwanted extra runs to over 50, including *Civilization VI*, *Elder Scrolls Online*, and *Conan Exiles*. The online backlash has prompted many publishers to remove it, and others have promised to.

Red Shell (yes, a *Mario Kart* reference) is a marketing tool to track the effectiveness of adverts; it watches to see whether you visit marketing campaigns on Facebook, Twitter, and the like (only while the game is running). No personal data is collected, and nothing sold on. However, it tracks online activity without express permission—naughty, naughty. Having your data harvested by a free game may be an acceptable part of the deal, but when you've laid out cold hard cash, you expect better than this. **-CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

SAVED FROM PREDATOR

Researchers have developed a graphene film that acts as adaptive thermal camouflage, effectively masking hot objects.

FACEBOOK TESTS AR ADS

Try that lipstick first, virtually at least, as new augmented reality ads put products on people.

LOCATION IS PRIVATE

The Supreme Court has ruled that where you were or are is your business, unless a warrant says otherwise.

TRAGEDIES

GAS PUMP HACKED

Detroit police are looking for two thieves who remotely stopped a gas pump's fuel cut-off and made off with about 600 gallons of gas.

EXACTIS DOES IT AGAIN

After last year's data breach, this time details on 230m Americans were left on a public server.

TRACKER TOO REVEALING

Polar has pulled its publicly viewable map, which revealed where you were exercising, even if that was in the White House.

Fortnite Players Go On a Massive Spending Spree

FORTNITE HAS OVER 125 MILLION PLAYERS. It's free, but that hasn't stopped its developer, Epic Games, from earning big. In May, it coined an estimated \$318 million. It's pulling in a million a day on the mobile version alone, and this is before the Android version is launched later this year. Total earnings for the year are expected to top \$3 billion.

This cascade of cash comes from in-game purchases: the Battle Pass, which unlocks rewards; and cosmetic frippery, such as skins and emotes. Research by LendEDU reveals that 68.85 percent of players have parted with cash, at an average of \$84.67 each. For 36.78 percent of those, this is the first time they've made in-game purchases.

What do players get for this cash? Not much really; the "enhancements" don't offer any advantage to gameplay. This may sound like a bad deal, but it's a smart move. If the in-game purchases gave an advantage, it's no longer a "free" game, it's pay-to-win, which is never that popular. This marketing model isn't new, but nobody has seen it on this scale before. It doesn't hurt that the game is awesome, but Epic Games has made a superb job of turning success into dollars. *Fortnite* entertains its players to the point where they'll happily pay for a new suit that does nothing but look flash. Effectively, the more dedicated—and richer—players subsidize the average Joe, without unbalancing the game. **—CL**



Fortnite's players are shelling out \$10 million a day or more.

Congress Questions Gmail Privacy

Google has permission to scan your Gmail messages; the company is geared around data collection, after all. However, it has emerged that engineers at third-party app developers Return Path and Edison Software have been reading them, too. Both claim to have consent due to Gmail's terms and conditions. The Senate Committee on Commerce, Science, and Transportation has sent a letter to Alphabet's CEO, Larry Page, asking for clarity. It may be technically above board, but it goes beyond people's expectations. When you accept the terms for one company, you don't expect data to be handed on for examination by others. **—CL**

Twitter Kills 70m Accounts

In the war on trolls and fake accounts, Twitter is deleting one million accounts a day, and has wiped 70 million since May. It has issued warnings that users will probably see a reduction in their number of followers. The vigorous attempts to clean house shows a shift of focus at Twitter. It previously championed free speech above all else. Del Harvey, VP for trust and safety, said, "Free expression doesn't really mean much if people don't feel safe." How many accounts are fake is difficult to estimate; Twitter reckons it at five percent, other studies put it at 15 percent or more. It is expected that Twitter's numbers will flatten out or even decline for the second quarter. **—CL**



\$399 SURFACE GO SURFACES

Microsoft takes another stab at students

MICROSOFT'S SURFACE PRO has been a success, to the surprise of some, as Microsoft's record with PC hardware is patchy. It has a funky, moderately innovative design, and an air of class. The smaller Surface models fared less well, initially being underpowered, and lacking full x86 compatibility. Microsoft stopped selling the previous small model, the Surface 3, in 2016. Now it's back with the Surface Go.

The Surface Go follows the established design pattern with a detachable keyboard, a back stand, 3:2 Gorilla glass touchscreen with stylus support, front and back cameras, and a magnesium case. Only it's smaller and lighter than any previous model at a svelte 9.6 x 6.9 inches, and just a third of an inch thick. It weighs in at 1.15lb. The 10-inch screen has a resolution of 1800x1200, which gives a pixel density of 216 per inch.

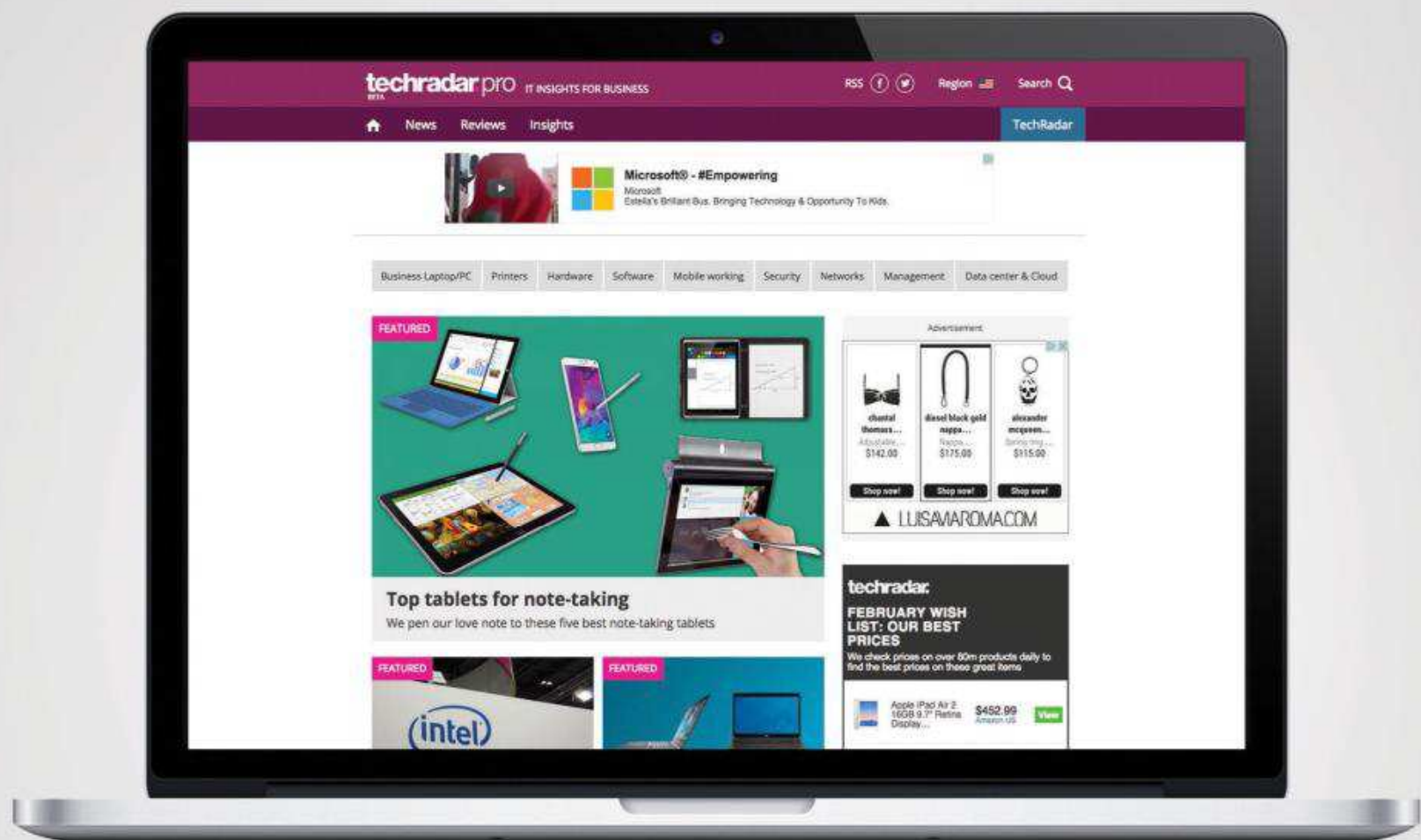
Inside it gets a proper Intel engine, as opposed to a weedy Atom one. The Pentium Gold 4415Y is a dual-core Kaby Lake part, and runs at a base clock of 1.6GHz. There's either 4GB or 8GB of memory, and 64GB or 128GB of storage. It runs Windows 10 Home in streamlined mode, although you can change up to full-fat Windows. Battery life is quoted at a useful nine hours. The base model sells for \$399, about half the price of a Surface Book Pro. The range tops out at \$549, with more models to follow.

An obvious target for the Surface Go is education, a competitive and potentially lucrative sector; every student wants a tablet or similar. The Surface Go has a hill to climb, as Apple's new entry-level iPad is \$329, and Chromebooks are cheaper still.

It's not just for students, though. This is a lightweight and rugged Windows machine, with a vast catalog of legacy applications (it's a proper Pentium, see?), and an all-day battery. It'll come in handy in a lot of other places, too; we can expect these to be carried around at work and home. It looks as if Microsoft has pitched this neatly. **—CL**

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Jarred Walton

TECH TALK

The Race to 10nm, 7nm, and Beyond

INTEL HAS BEEN at the forefront of the silicon microprocessor revolution since the beginning—it's currently celebrating the 40th anniversary of the 8086 processor, with the limited run Core i7-8086K likely being sold out by the time you read this. If you wanted a look at the best process technology, Intel has traditionally been the leader.

Look at 22nm: Intel launched its Ivy Bridge CPUs in 2012, and it was the first manufacturer to move to FinFET tech. Competitors didn't reach 20nm until 2014, and it was considered inferior to Intel's 22nm.

Since 2012, however, there's been a continuing shift in process technology leadership. Intel's Broadwell chips sort of arrived in 2014, but only for smaller U-series parts, with mass availability in 2015. Broadwell on the desktop was almost a no-show, but the Skylake refresh came in on schedule, only a few months after Broadwell. But 2015 also saw the launch of 14nm chips by Samsung, and 16nm from TSMC entered mass production by early 2016—and all the manufacturers now offer FinFET.

The numbers don't tell the whole story, of course. Intel's 14nm process has a smaller fin pitch, gate pitch, and interconnect pitch than the others, so it's still denser and in some sense better. And that's a good thing, because Intel's transition to 10nm is seriously delayed. We're currently on the third generation of 14nm chips from Intel (Skylake, Kaby Lake, Coffee Lake), and Whiskey Lake will be the fourth 14nm CPU, slated for release later this year. The original plan was for Intel to roll out 10nm production by 2016, so volume production for the process has been delayed by three years.

Technically, Intel has released a small number of 10nm chips, but the only offering right now is the Core i3-8121U, a dual-core part for laptops. Except, there are indications even here of problems, as the chip doesn't include

working graphics. The last time Intel shipped a laptop-focused CPU without graphics was in Penryn, back in 2008.

Companies like Samsung, TSMC, and GlobalFoundries aren't just closing the process technology gap—they're claiming the lead. Samsung has been shipping 10nm products since mid-2017, with the Exynos 8895 and Apple A10X using the process, and TSMC has been shipping Apple's A11 since September 2017. But if you look at the fin pitch, gate pitch, and interconnect pitch, Intel's 14nm isn't

that different from Samsung's 10nm. Process technology has become a numbers game, and marketing plays a role—TSMC basically rebadged its 16nm process as 12nm,

because the lower number looks better compared to Samsung's 14nm. Even if Samsung and TSMC 10nm don't have a lead in process tech compared to Intel's 14nm feature sizes, TSMC is due to begin shipping mass-production 7nm parts later this

year. The feature sizes on TSMC's 7nm node are competitive with Intel's 10nm node, and potentially arriving 6–12 months before Intel starts shipping volume 10nm parts. Samsung's 7nm node also meets or beats Intel's 10nm, and should begin volume production before Intel's anticipated mid-2019 date.

The importance of smartphones and what they represent can't be overstated. It's not that desktop or laptop PCs are going away any time soon, but the rise of the SoC has given companies like Samsung and TSMC the finances and other resources to potentially beat Intel in a market that it has dominated for almost 40 years. It's also yet another sign of the death of Moore's Law, and future refinements are only going to become more difficult.

Like all good exponential growth patterns, process technology scaling is reaching the end of the road. Silicon and copper atoms are only about 0.14–0.21nm in size, and we're fast approaching that limit. TSMC has 5nm on its roadmap for 2020, but don't be surprised if future node improvements start to look like the last three years of incrementally smaller improvements.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

Mass production of a 10nm Cannon Lake wafer is still a year away.



THE LIST

THE MOST EXCITING GAMES OF E3 2018

8



MAVERICKS PROVING GROUNDS 100-player battle royales? Pah. How about 1,000 players at once?

7



STAR CITIZEN Not new, but Alpha 3.2 was unveiled at E3, with some gorgeous combat on show.

6



STAR CONTROL: ORIGINS Stardock's redux updates the classic mix of humorous galactic diplomacy.

5



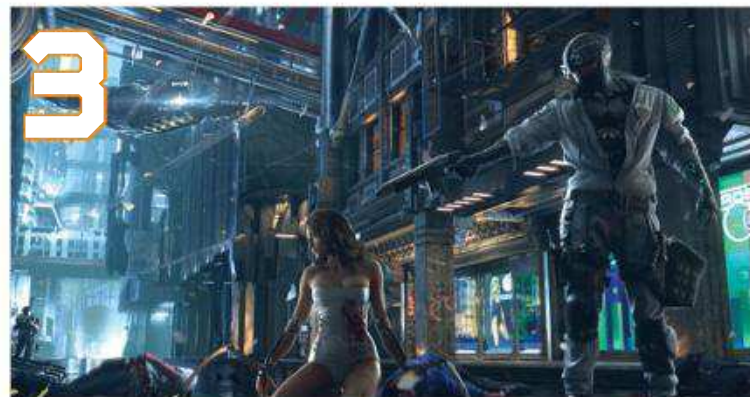
BETHESDA *Fallout* goes multiplayer, *Elder Scrolls 6* is coming, and Bethesda is heading to space with *Starfield*.

4



SATISFACTORY This first-person factory builder prettifies the irresistible gameplay of *Factorio*.

3



CYBERPUNK 2077 Dystopian future? Check. Lore-packed license? Check. From *Witcher* studio? Sign us up.

2



SKULL AND BONES We saw this pirate-'em-up's multiplayer, along with that essential element: a kraken.

1



NEO CAB Drive a future-Uber as an emotion-hindered human while AI is desperate to take your job.



Alex Campbell

OPEN SOURCE

Need a Summer Weekend Project? Try Docker

IF YOU WANT to make the most out of a VPS, home server, or NAS, learning how to use a container system, such as Docker makes life a lot easier, especially if you want to run multiple web apps, such as WordPress or Plex. Luckily, containers aren't so scary to learn or use....

I used to be skeptical about the whole container and Docker thing. "Why would I want a container when I can just install things like I'm used to?" I would ask the void. The answer is pretty easy to understand when you try to install more than one app.

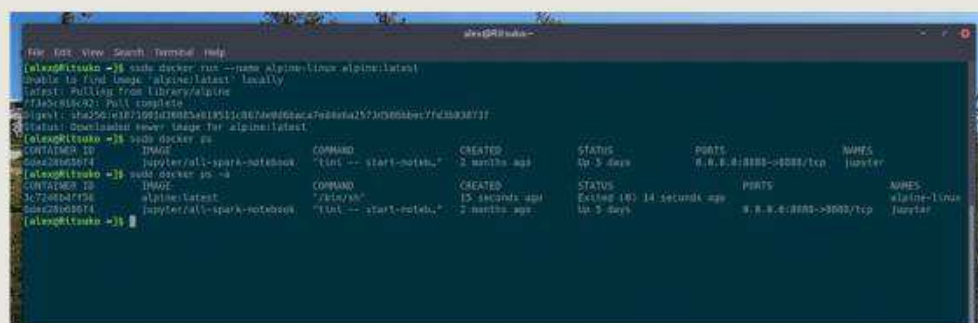
If you've ever run a server at home or on a shared host, upgrading an app can be a touchy experience. Some applications rely on specific features of their dependencies, or software that the app relies on to run. When upgrading your app, the new version may rely on an updated dependency. But if you're running another app alongside your web application—like a database, for example—that app may cease to function properly if the dependency is upgraded.

Another situation is common: A web app—such as WordPress—updates itself, but requires a new version of some underlying software, such as PHP. If you upgrade too soon, your distro may not have the new version of the dependency available in its repositories, leaving you with errors in the web app.

Containers solve this problem by doing something that had before been the preserve of virtual machines. Unlike virtual machines, containers don't require exclusive and pre-allocated CPUs or memory. Containers can use the current machine's kernel, but simulate the rest of the OS's filesystem. Essentially, an Ubuntu Docker container can run on a Fedora system. From within the container, it appears as though the system is running Ubuntu,



Because it's painless to start, stop, and delete containers, it won't take long to get most things right.



Running a minimal Docker container image is a simple command.

with its own versions of Python, PHP, or any other apps it needs.

Updating a container does not require you to update the system. An updated container gives you the whole shebang: the app and its dependencies. Containers also have their own networking facilities and IP addresses on the host system. This allows containers to talk to one another through ports—like port 8096 for Emby. Docker networking also allows the use of Docker containers as training tools.

With all this goodness, should you run Docker containers at home? It depends. If you're trying to run multiple services like Sonarr, Plex, and MySQL on one machine, I'd say yes. Many of the containers you'll find on Dockerhub have pretty sane defaults. As it's painless to start, stop, and delete containers, it won't take long to get most things right.

Is there a downside? You bet. For a start, it's another technology to learn. Some of the more advanced

features of Docker containers can be tricky to use. Getting volumes, networks, and other configs set up just right can be a pain. And Docker for Linux does not work on the Windows Subsystem for Linux.

On top of this, Docker containers aren't secure by default, as they run as root. This can be mitigated by running Docker with user namespaces, but the setup and administration consequences are non-trivial. Recently, several images hosted at Dockerhub were removed because the images contained crypto miners and other malware. As a rule, I try to use official container images or images from www.linuxserver.io.

The best part about Docker containers is that they're (generally) free. Take time to experiment. They aren't as scary as you might think.

Alex Campbell is a Linux geek who enjoys learning about computer security.

HEAD TO

BY ALEX COX

Keyboards: Mechanical vs. Membrane vs. Optical

There’s a lot going on in keyboards, and it’s time to put the key technologies in a jar and shake them. Note, though, that by membrane, we’re referring to dome-switched keyboards (rather than the flat variety you might have on your microwave), and we’re looking at the Wooting One as our prime example of optical. Mechanical, at this point in its evolution, is something we can’t pin down as accurately, so we’re taking a broader view of that...

ROUND 1	ROUND 2	ROUND 3
Responsiveness We have convinced ourselves that the faster a keyboard reacts, the better it is. And in many ways, we’re right: Earlier key switch actuation reduces tendon strain by allowing a lighter touch and preventing the shock that bottoming out sends back down to the wrists; it also gives you that extra femtosecond advantage in Twitch games, though if you’re not a South Korean <i>Starcraft</i> pro, it isn’t as valuable as you might think. Whatever the importance, membrane loses out here. Certain designs may have a dome and actuator that squish the appropriate contact on the circuit board more quickly, but you’ll almost always find yourself going full-travel with your switches. Mechanical is a mixed bag, given the difference in actuation points and spring stiffness between various key switches, although the vast range of options means something suitable—and suitably sensitive—is always around the corner. But optical switches, at least if we’re looking at the mechanical-optical combo of the Wooting One, can be as responsive as you like, offering the chance to customize your actuation point to the precise level your fingers love. All this, plus optical switches typically have the shortest debounce time. Winner: Optical	Tactility There are differing schools of thought on the subject of keyboard feel, and it’s difficult to pick a winner without offending a small contingent of the keyboard community. It’s very easy, for example, to belittle membrane fans, those poor deluded masochists who love to mash down on squelchy rubber domes, rather than treating themselves to the proper experience of mechanical switches. But we’d be wrong and obviously biased to do so, so we won’t. And there are mix-up boards, so-called “membranical” chimeras, which go some way to improving that feel. Equally, there are also mechanical keyboards on the market that feel, at least to these fingers, like utter garbage—take away the bite, and it’s very possible to make a mess of your key switches. Optical, despite originating in the 1960s, is still evolving, so there’s not a lot to choose from at this stage, certainly not the variety of mechanical-only switches. In theory, optical keyboards should give rise to mechanical key switch designs that don’t have to confirm to the usual norms, and therefore end up feeling quite different, although continued development of the format will really depend on its popularity taking off. Winner: Mechanical	Value We don’t suggest that you select a keyboard on the basis of its low, low price—although you’re welcome to, if you’re the kind of person who also buys the cheapest toothpaste they can find—but there are times when spending a little less makes sense. Maybe you want a spare, maybe you want to drive a Raspberry Pi without unplugging your main keyboard, perhaps you want to try making a macro keyboard (see page 68), or use it in an environment where other switches are likely to fail. In these circumstances, or if you really don’t have the money to spare (in which case, forgive our facetiousness), a membrane board is by far your best bet. Membranical hybrids trend slightly higher in price than your \$8 stock membrane, but offer more fancy-pants frippery for the bucks. Going mechanical is not, even at the base level, what we’d consider cheap, and it’s very possible to spiral way out of control with the spending if you start going down the custom switch, custom layout, custom key cap route. Optical, given the extra complexity of its switches, also has a higher price at the low end. So, in this category at least, there can be only one winner. Winner: Membrane

HEAD



Mechanical: Originally a Cherry staple, mechanical switches now have all sorts of variants.

Membrane: Cheap, quiet, easy to manufacture, and boring to type on.

Optical: Based on a mechanical switch, but with more lasers.

ROUND 4

Lighting

RGB seems to be most prominent in the mechanical domain, but many physical switches aren't particularly friendly toward it. Glance at the average mechanical board, and where the key labels are on each key—chances are, they're off-center, pushed toward the upper edge of the key, because their LEDs have been pushed out by the switch mechanism. There are some varieties that negate this (Logitech/Omron's Romer-G switches, for example, which we love, but others aren't so keen on) by creating a hollowed-out mechanism that puts the LED at its core for central labeling; this reduces the light-flooding that base-mounted LEDs put out, which is either a boon or a curse, depending on your preference for gaudiness.

Credit to the new generation of China-import membrane-mechanical hybrids for bringing the price of solid lighting options down. There's nothing stopping membrane keyboards pulling off the same RGB tricks that mechanical boards can—and examples such as the Razer Deathadder Chroma do just that. Optical isn't left out: Even though its switches rely on light for actuation, just about every example we've seen manages strong out-of-switch illumination.

Tie: Mechanical, Membrane, Optical

ROUND 5

Reliability

Keyboard manufacturers love to crow about the number of activations their switches can pull off. Usually, this is meaningless. What happens after that? Do they combust? Turn to dust? Stop working? Even the most prolific typist or gamer is unlikely to get to the multi-million press mark before their next keyboard upgrade, so few of us find out the truth. What we do know is that mechanical switches have the quickest route to failure, as they rely on precise interaction between moving parts.

Optical switches, presuming they don't get caked in dust or use defective sensors, should last the longest, as their actuators will live on even after the mechanical portion of the switch has ceased to function properly. Membrane, as long as the circuit sheet remains intact and the contact points remain un-crumpled, isn't short-lived either. Perhaps the better metric, considering that many optical and mechanical keyboards allow you to replace the keys, is what these keyboards can withstand—and while we'd be tempted to give membrane the win, given the existence of silicon-coated rollable keyboards that will work when submerged, we're shuddering at the thought of them.

Tie: Mechanical, Membrane, Optical

And the Winner Is...

We're massively excited by the potential of optical keyboards to change the way we type. The fast switches and open design space are hugely interesting, and analog sensitivity has a lot of potential—as does the ability to assign more than one function to a key, depending on how far down it's pressed, as with the Wooting One. But while we've said that price shouldn't be a consideration, the fact is that, right now, mechanical keyboards offer more variety for less money, or more customizability if you want to throw in a thick roll of dollars. Membrane keyboards are, at the same time, just as bad as they ever were and better than they've ever been, depending on if you're buying a cheap one or a more advanced membranical model. But we're enthusiasts, and we're typists and gamers, and there's still no real argument: The exact feel you want, the audible experience, the coolest looks, the deepest rabbit hole—they're all still in the mechanical realm. Don't let that stop you from trying something else, but if we were picking up a new keyboard, that's the way we'd go. 

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

- > Noisy NAS Drives
- > Dual 4K Displays
- > Update Failures

NAS Noise

I have a question regarding the Seagate IronWolf drives you've reviewed, and which are now in my Netgear NAS appliance. I have tried two different sets of these disks, so I'm fairly confident that I'm not having issues with defective hardware.

Did you test the drives in a network-attached system or a desktop PC? During idle periods, the disks make brief clunking noises followed by what sounds like writing to the platters every minute or so. This happens over and over, indefinitely. They don't make the noise when powered up in a drive dock.

I found one vendor that said the issue is caused by EPC (Extended Power Conditions). Seagate has a Windows-based utility that allows you to turn EPC off. However, pulling drives from a NAS and booting them up on a desktop doesn't sound like a good idea.

Did you run into the same situation, and do you have a suggestion for solving it? For now, my NAS is banished to the basement. It's just too loud for my study. **-Bill**

THE DOCTOR RESPONDS: While the Doc doesn't have any IronWolf drives in his testing



Seagate's IronWolf drives are designed for NAS applications, but still require optimization.

facility, there are some general steps he recommends to help troubleshoot your noisy NAS.

First, consider physical remedies. You no doubt know that it's normal for disks to click and whirl during reads and writes. But if they aren't secured properly, harmless sounds may be amplified as a result of vibration. Rubber grommets between the drives and trays go a long way to isolate each mechanical device.

Rattling metal doesn't seem to be the root cause of your conundrum, though, particularly since a number of

forums have IronWolf owners discussing similar symptoms. Seagate's own troubleshooting guide calls out hard clicks as a normal part of the drive heads parking. However, it's possible that they shouldn't be parking so often, or so abruptly.

Fortunately, the timing of this behavior can be altered. Seagate previously made the software needed to tinker with its drives available to select customers (it's command line-based and a bit complicated, after all). But now its complete SeaChest suite is accessible on its site, along with a detailed instruction manual. That's the diagnostic package you were referring to for disabling Extended Power Conditions. Only, it may not be necessary to disable EPC altogether. Seagate's PowerChoice Technology is tiered into successively more aggressive capabilities, so try turning off the top-level features first to avoid losing all power-saving functionality underneath.

Because standalone Linux and Windows versions come packaged in the same download, it may be possible to run the SeaChest utilities directly on your NAS, without relocating drives to your PC. Incidentally, the same software is used to update the IronWolf's

firmware. Navigate to <http://seagate.com/support>, click the "Software Downloads" link up top, then type in your drives' serial numbers to search for a newer build. At the same time, hit Netgear's site for any updates that might be available for your NAS. With improved support from both manufacturers for each other's hardware, it should be possible to dampen acoustic issues.

Doubled Display

Hi Doc, Do you have any recommendations for a graphics card that I can drop into an older Z77-based motherboard and add support for two 4K displays at 60Hz? Cost is more important than performance; I only do some light-duty strategy gaming, and this is mainly a productivity rig. **-Dan**

THE DOCTOR RESPONDS:

Driving a pair of 4K monitors at 60Hz isn't a problem for most modern add-in graphics cards. However, if you plan to do any gaming on even a single 4K display, the Doc would recommend an affordable model with 4GB of onboard memory. AMD's Radeon RX 560 is one option priced around \$160, or a GeForce GTX 1050 Ti sells for roughly \$180.

submit your questions to: doctor@maximumpc.com

Storage Decisions

Hi Doc! When someone has two storage devices in their PC, and one of them is a solid-state drive, what is the advantage of using it for storage in lieu of a mechanical disk? I recently purchased a new laptop configured with two drives: one standard 1TB hard drive (configured as C:) and a 3TB SSD (set up as D:). My C: drive quickly filled up, and the laptop started running slower. So, I replaced the 1TB disk with 2TB of storage.

This got me wondering why the laptop manufacturer configured the SSD for storage. Shouldn't it have been the secondary drive for faster boot-up? There's no advantage to having the SSD if it's not the C: drive, right?

If a solid-state drive is more durable, more efficient, and faster than a standard hard drive, why are computer manufacturers still outfitting new laptops with a standard hard drive and SSD, with the operating system running on the HDD? **—Bob McElwain**

THE DOCTOR RESPONDS: Something about that configuration doesn't sound right. Although 3TB SSDs do exist, they cost thousands of dollars, and wouldn't typically be found in a laptop. Moreover, a mobile device with that much solid-state storage doesn't really need a 1TB mechanical disk for user files.

It all comes down to dollars. Ultra-fast SSDs cost a lot more per gigabyte than hard drives. So, you fill their limited capacity with data that stands to benefit most from high performance. Meanwhile, movies, music, pictures, and documents can live on spinning disks, as they gain nothing from faster transfer rates or lower latency.

Now, between the OS files you want on your SSD and the multimedia library stored on mechanical storage, there are applications that can go either way. Games, for example, usually aren't bottlenecked by disk I/O. Rather, they spend most of their time waiting on



For under \$200, a GeForce GTX 1050 Ti 4GB offers plenty of 4K-capable outputs.

your graphics card or CPU. But a game on an SSD still loads textures and switches between levels faster than one on a hard drive. As a result, the Doc puts his games on solid-state drives whenever capacity permits.

Expect SSDs and mechanical disks to coexist for years to come. While advances in NAND flash tech make larger, lower-cost SSDs possible, our appetites for more space mean big hard drives are important in the storage hierarchy.

Windows Update Fail

Hi Doc, I don't know if you've addressed this issue before, but it has to be one of the worst I've ever seen. As a retired IBM software engineer, I am appalled at the problems related to the forced automatic update of Windows 10. How can it be acceptable to perform a two-hour installation, only to have the process roll back without any indication of what went wrong? Additionally, after failing, it repeats the same update attempt with the same results a week or two later.

Why isn't Microsoft able to definitively pinpoint the problem so it can be corrected? Googling the return code, 0x8007042b, provides no clue except to state that if disconnecting USB devices fails to correct the issue, you must perform a clean install of Windows 10. Even a full backup/restore isn't guaranteed to work; again, the problem repeats itself over and over.

Do Microsoft's engineers have any idea how many

wasted hours go into reinstalling their operating system and everything else on top of it? IBM had a manual called "Messages and Codes" that fully detailed every error, along with its meaning and corrective action. So, now it appears I'm forced to disable all updates. What can I do to pressure Microsoft to get its act together?

—AF Donato, retired SE

THE DOCTOR RESPONDS:

In Microsoft's defense, its own repository of Windows documentation concedes that System Error Codes are broad, and can occur in many hundreds of locations. This means their descriptions cannot be very specific. But there's a couple of steps you might want to try, other than disconnecting USB devices, or completely reinstalling Windows.

First, try running Windows Update after performing a clean boot, which loads up a limited number of software drivers and startup apps to minimize the chances of a conflict. Bear in mind that you must be logged in as an administrator. Assuming you're running Windows 10, type "msconfig" into Cortana's search box, and click on "System Configuration." Switch to the "Services" tab, select the "Hide all Microsoft services" checkbox, and click "Disable all." Now move over to the "Startup" tab and "Open Task Manager." Under that window's "Startup" tab, select each item, and click "Disable." Close the Task Manager, return to the System Configuration window, and click "OK." Restart

your system before trying to reinstall the update.

Microsoft also publishes a Windows Update Troubleshooter. If you're using Windows 10, visit <https://aka.ms/wudiag> to grab the diagnostic cabinet file. Follow the wizard's prompts to clear up any outstanding issues preventing Windows Update from completing successfully.

If all else fails, there's always the option to speak up with your wallet.

Reinstalling Windows

Doc, If anyone can answer this question, it's you. My installation of Windows 10 has decided to stop loading Edge, along with several other standard apps like 3D Builder, Microsoft Store, Phone, and Print 3D. Is there a way to reinstall/repair Windows 10 without losing my programs, shortcuts, settings, or data? I'd like to end up with the same system, except fixed. I'd hate to start from scratch. Help me, Obi-Wan Kenobi! **—TPK**

THE DOCTOR RESPONDS:

Microsoft offers a few ways to restore the functionality and performance of a fresh Windows 10 install, including the reset (open Windows Settings, click "Update & Security," and select the Recovery pane) and Fresh Start (open Windows Defender Security Center, click "Device performance & health," and select "Additional info" under the Fresh Start description). With a reset, you lose your apps, though. A fresh start preserves personal files and some settings, but also sacrifices most apps.

Alternatively, perform a repair upgrade. Download the Media Creation Tool from Microsoft's website, which you can use to grab the .ISO corresponding to your copy of Windows. Mount that file by double-clicking it, then run the setup file within. Follow the wizard, and you basically install Windows 10 over your existing copy, preserving apps, settings, and files in the process. 🔄

THE PERFECT HOME THEATER

How to spec, build, and set up a home theater PC—whether it's for gaming, streaming, or a simple plug-in NAS, we break down exactly what you need

TAKE YOUR MIND BACK for a moment. The year is 2007, Steve Jobs has just announced the iPhone, the Indianapolis Colts have finished smashing the Chicago Bears in this year's Super Bowl, and Windows Vista has now been out for three whole months. Microsoft's operating system brought with it a hefty installation size, a ton of unnecessary resource-consuming processes, and—more importantly for us—access to the Windows Media Center across all of the various editions of the flagship OS.

For the first time (outside of the Windows XP Media Center Edition OS, of course), there was an intuitively designed, integrated user interface developed specifically for simpler input

methods, such as a remote, and baked directly into the operating system itself. This is arguably the one thing that Windows Vista got right, and it would later inspire the Xbox 360's media center as well, eventually leading on to the development of Kodi.

We've built rigs around the concept, we've tinkered with features about backing up your legally obtained media collections, and we've delved into how to stream the latest 4K content direct to your home computer. Yet we've never combined the lot. Welcome, then, to *Maximum PC's* first foray into the technological territory of building your own perfect home theater and content-consumption computer. —ZAK STOREY





SYSTEM SELECTION

So, you want to build your own home theater PC—what are your options?

WHEN IT COMES to choosing the hardware for your HTPC, unsurprisingly, like the rest of our most prestigious hobby, it's very easy to get swept up in one of those buying frenzies, and lay down way too much cash for a machine that's far more powerful than you really need. GTX 1080?

Intel Core i7-8700K? 16GB of DDR4? Sure, you could shell out for all that, but unless your use case scenario includes some exceptionally high-end gaming on the side of your entertainment shenanigans, the reality is that it would be total overkill for your requirements. So, then, let's break it

down: What exactly do you need for a home theater PC? Well, the truth of the matter is that Kodi will actually run on everything from the Raspberry Pi all the way up to a \$10,000 super-tower, so let's take a look at some example systems to get a feel for the whole concept.

CUSTOM-BUILT PHANTEKS EVOLV SHIFT

PROS

- ✓ Choice of hardware options, from processor to GPU, memory, and storage.
- ✓ Advanced cooling solutions allow for noise reduction.
- ✓ Possible to house all of your storage in a single unit.
- ✓ Wide selection of home theater-specific chassis.
- ✓ Better access to more plump I/O and audio solution connectivity.
- ✓ Absolutely perfect for couch gaming sessions.

CONS

- ✗ Potentially very expensive, especially if you invest in a GPU.
- ✗ Most likely has a higher power draw than other options.
- ✗ More time-consuming to set up, and maintenance and warranty are on you.
- ✗ Requires full Windows licenses, purchased separately.
- ✗ 4K streaming capability dependent on hardware configuration.
- ✗ Substantially larger form factor than other solutions.

BUILD IT
Step-by-step guide
PG. 70



RASPBERRY PI?

Ah, that old favorite of ours, the Raspberry Pi—modern-day insane computing made manifest in a tiny device that fits in the palm of your hand. Capable of powering 4K resolutions on the cheap, you can indeed install the likes of Kodi on a Raspberry Pi with little fuss, and it'll run identically to its other, bigger, Windows 10 brothers, seen below. It's super-affordable, too, coming in at \$35 for the Pi 3 Model B. The only downside is that the vast majority of your media will need to be stored on an external hard drive or something similar, and connected via USB 2.0, meaning at max the only content you'll be able to drive through

it is standard 1080p stuff, outside of streaming, of course.

There's a wealth of other streaming boxes available from some of the big names, including Amazon's Fire TV Stick, Roku's Streaming Box, Google's Chromecast, and even the Apple TV, if your budget can stretch that far.

If you're dead set on using Kodi, though, your best bet is to grab a Raspberry Pi. A lot of the third-party sticks we've mentioned run proprietary software and interfaces, and although they may provide you with some of the utility of Kodi, installing it on there after the fact is a bit of a nightmare.



GIGABYTE BRIX BAREBONES

PROS

- ✔ A barebones unit provides some ability to choose configuration.
- ✔ Thanks to mobile parts, noise is almost non-existent.
- ✔ Far more affordable compared to a fully grown HTPC.
- ✔ Super-small footprint; can be VESA-mounted to the rear of TVs, or hidden.
- ✔ Easy to install hardware, and to initially set up.
- ✔ Usually comes with a Windows license, dependent on manufacturer.

CONS

- ✘ Far less powerful than the alternative.
- ✘ 4K streaming still dependent on hardware configuration.
- ✘ You tend to get less bang for your buck.
- ✘ It comes with limited built-in storage.
- ✘ Less thermal capacity compared to the alternative.
- ✘ Not as much I/O in comparison with the custom-built option opposite.





HARDWARE CONSIDERATIONS

A guide to all the gear you need to power your media machine

YOU'VE DECIDED to build your own HTPC. You've got enough media lying around that it's about time you ripped the lot, saved some physical space, and threw

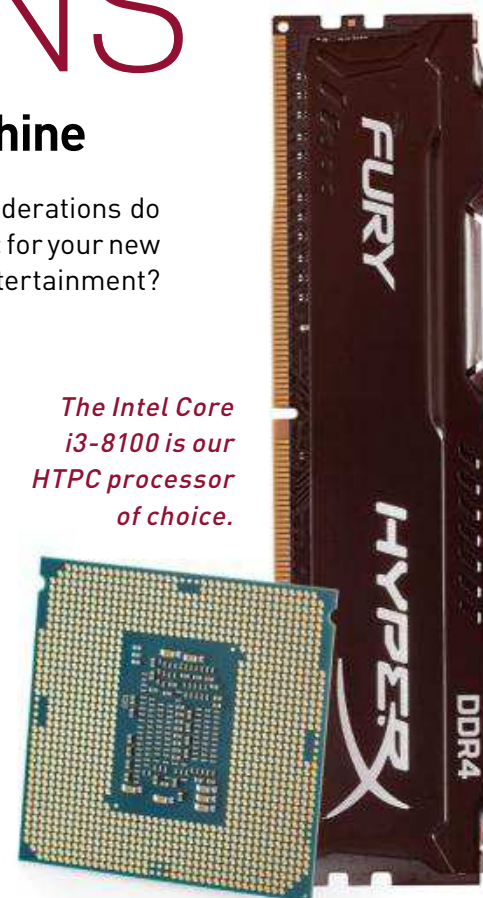
it into storage on and offsite. What considerations do you need to make when choosing the spec for your new micro-box of media management and entertainment?



MSI's Z270i is a good example of an HTPC mobo.



Samsung's 860 Evo M.2 is perfect for space-saving.



The Intel Core i3-8100 is our HTPC processor of choice.

MOTHERBOARD

Choosing the ideal motherboard for your home theater PC is crucial for starting out on the right foot, and unsurprisingly, it all comes down to connectivity. Finding a board with a solid rear I/O is key. For those running more advanced audio speaker solutions, you're going to want something with optical audio-out (also known as TosLink or S/PDIF), plenty of USB ports for your DAC/amplifier's infrared reader, wireless controllers, and other peripherals, and, of course, some form of graphics-out, such as HDMI or DisplayPort (although DP won't provide you with audio direct). If 4K streaming is your game, you're also going to want to get yourself a motherboard that has support for HDCP 2.2, of course.

HDCP is a form of DRM that ensures you can't rip 4K content by using an intermediary device between the system and the TV. In short, it's Hollywood's way of protecting its property in the modern digital age. That said, if you can live without 4K, any motherboard with a display-out will get you 1080p streaming, no worries.

Everything else after that is secondary—you won't need extensive overclocking capability, nor a multitude of fan headers, advanced power phase designs, or even, dare we say it, RGB. The cheaper motherboards will suffice here.

STORAGE

When it comes to storing media, there's a plethora of solutions. On a very basic level, however, we'd almost always recommend running your HTPC on some form of flash storage, or a SATA SSD, as a bare minimum. You want this thing running quick and snappy, after all, otherwise you may as well be using your integrated smart TV. A PCIe SSD is overkill for these builds, but if you're trying to minimize space usage, you can pick up a snappy M.2 SATA SSD on the cheap.

For everything else, spinning platters are the name of the game, and old-school 1TB, 2TB, and 4TB hard drives should work a treat for everything from games to music to films. Keep in mind what chassis you're using and whether it has support for 3.5-inch drives. If it only supports 2.5-inch drives, like the Phanteks Shift featured here, for instance, you can opt to purchase a 2.5-inch old-school hard drive instead. Storage might be a touch reduced, and you might have to pay a little extra, but there's still a ready selection available. For instance, you can pick up a 2TB WD Blue 2.5-inch drive for a little over \$80.

If gaming isn't important for this setup, you could go for something more serious in the form of a NAS. This is ideal for systems such as the Gigabyte Brix or a Raspberry Pi, and is far less time-consuming, especially if you already have one in your household.

CPU & MEMORY

Right, memory first. Let's be realistic: You don't need a lot of memory for a rig like this. Anything more than 16GB and you're kidding yourself. In fact, outside of some intensive couch-gaming sessions, even 16GB is perhaps a little too exuberant. If it's just media streaming you're after, 4-8GB of single-channel memory should cut the mustard. Media streaming isn't that intensive, so cutting back here is a quick and smart way to save a buck or two to spend on a better CPU, GPU, storage, or even cooling.

When it comes to processors, on the other hand, that's a different matter. If you're after the holy grail of 4K streaming from the likes of Amazon or Netflix, you'll want a CPU with an integrated GPU that can power 4K @ 30fps and support the HDCP 2.2 encoder.

For Intel, this is anything past the seventh generation of chips (aka Kaby Lake). The entire range and above—from the mighty Core i7s to the lowly Celerons—all support HDCP 2.2 and 4K resolutions on the integrated GPU. We recommend either the Core i3-8100 or the Pentium G5400.

For AMD, pickings are far slimmer. You're limited to either the Ryzen 5 2400G or the Ryzen 3 2200G, as they're the only two Ryzen parts with integrated GPUs. If you want to do a bit of gaming on the side, we recommend the 2400G as your chip of choice.



From left to right: *Samsung is usually a good bet when it comes to TVs, too. Naim's Uniti Atom is the perfect AIO amplifier. Logitech's Harmony Elite has long paved the way for PC remote greatness.*



TV: 4K VS. 1080P

The likelihood is that if you're considering building a home theater PC, you'll have a TV in mind—either the one that's already in your home, or one that you want to buy for it. Maybe this is a new setup for your chillaxation room (that's a thing, we're told), but there's a few little prerequisites you'll have to check ahead of time.

Again, first and foremost, you're going to want to make sure your TV supports—yep, you guessed it—HDCP 2.2. But aside from that, the rest of your TV choice falls to you. Do you want 4K, 1080p? 42-inch? 55-inch? Really, there's not a lot we can recommend at this point, because most of it is going to be down to personal preference. There are specific TVs out there that do support higher refresh rates (120Hz+), but a lot of those are overpriced, and with most TVs supporting 60Hz anyway, that's not too much to consider.

Then there's the question of projectors. There are 4K projectors available, but not many, and at a ridiculous cost. As TV panels have reduced in price, you're probably better off going with a TV, as opposed to those light-producing monstrosities.

The Q Acoustics M.2 Soundbar is a top choice.



AUDIO SOLUTIONS

Audio is another one of those mystical elements that fall more on the side of your choice rather than anything we can recommend. There's everything from soundbars to bookshelf speakers to tower speakers to integrated TV speakers. We've opted for a Q Acoustic 3050i setup—these mid-range floor-standing monitors are the perfect pairing for our PC build, and they look stellar to boot.

One thing to bear in mind when it comes to configuring your home audio is whether you're using powered or unpowered speakers. If it's the latter, you're going to need a speaker preamp to successfully get them to produce any audio at all. The best way to do this (budget considerations aside) is to invest in an all-in-one unit, such as the Naim Uniti Atom, featured on page 44. These often come with a combined DAC, too, providing you with better clarity and bass in your audio. That said, you can pick up an amp from Amazon for less than \$40 if you're not willing to splash so much cash on something so ludicrous.

PERIPHERALS

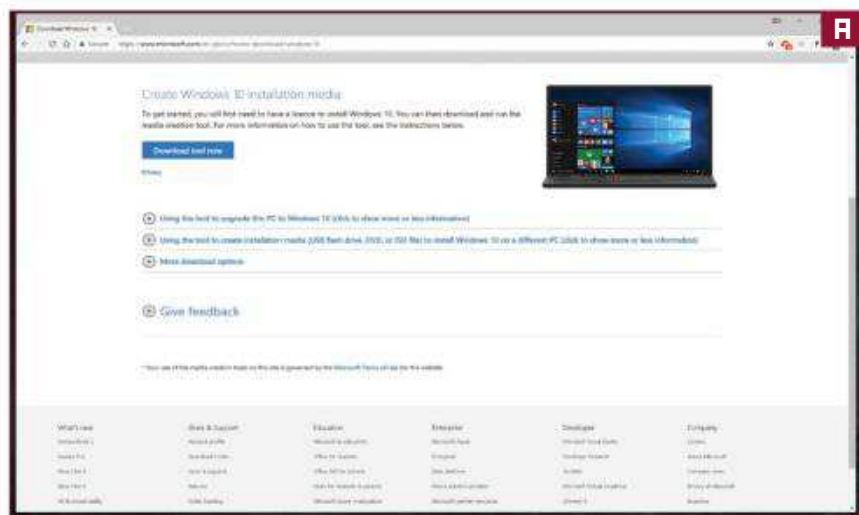
So, you've got your system set up, your TV on tap, and your audio booming—the big question is, how do you control it all? How do you turn that entertainment ecosystem into something more akin to a TV? You need a remote. Our favorite is Logitech's Harmony series, which ranges from \$50 all the way up to \$350. The theory is you condense all of your remotes into a single controller, and swap between devices on the fly. The Harmony Elite, Logitech's top-end model, comes with an IR receiver, too, for even more connectivity options, while the lower-end models connect over the Internet to your device. There are lots of apps that allow you to use your phone to control your HTPC, too.

If you're after something more PC-like, you could opt for a wireless mouse and keyboard combo. Our favorite is the Razer Turret. Its slim folding form factor, charging dock, and magnetic mouse and attached mouse pad make it one of the best available.

As for controllers, again there's a number you can turn to, depending on personal preference. We're a big fan of wired controllers, but you can opt for a number of wireless controllers from a range of brands—Razer, SteelSeries, and Logitech all sell wireless controllers for use on your home theater.

YOUR INITIAL KODI SETUP GUIDE

It's time to get down to the difficult part: installing and setting up the software



1 INSTALL WINDOWS

You need a full version of Windows on this rig for more compatibility later down the line, and there's a few important steps to take into consideration. Use the Windows Media Tool [Image A] to create a bootable USB stick with Windows 10, plug it into a USB port on your HTPC machine, enter the BIOS, and direct the boot order at the USB stick. Point the Windows installer at your main SSD drive, and begin the installation process.

» There's one important thing you need to remember during this HTPC install, and that's to only create a local account, and one without a password. Remember: This is meant to be a home theater PC, a switch-it-on-and-go machine, as opposed to something more secure that contains potentially confidential information.

2 DOWNLOAD KODI

So, you've installed Windows, your chipset is in, your video drivers are installed, and your system's running sweet as a nut. Next step is to get the correct version of Kodi.

» Head to <https://kodi.tv/download> and hit the "Windows" logo midway down. You're offered three different versions: the recommended build (Kodi v17.6 "Krypton"); the pre-release (Kodi v18 "Leia" Alpha 2); and the dev build (Kodi v18 "Leia" Nightly). We're using the recommended v17.6 variant for our install [Image B]. There are huge differences between 17.6 and 18 on a basic level, and many add-ons that operate on v17 don't work correctly on v18.

3 KODI FIRST RUN

Now you've got your download, click on the .exe, and install Kodi direct to your C: drive. There are no hidden toolbars or bloatware embedded here (we've checked), as Kodi's an open-source program, and is run directly by donations from the public.

» Once you've got it installed, you'll want to open up the program itself, and have a look around. At first glance, Kodi seems somewhat bland—a very simple and unsophisticated way of storing and accessing any media held on your system, without much flair. But don't worry, we'll sort that out shortly.

» It's a good idea in these early stages to take a look at the settings in depth. There's a ton of customization options here, and a whole

plethora of add-ons to get to grips with later down the line, so having a basic understanding of how the standard skin and its menus work is of paramount importance.

4 CHOOSE A SKIN

It's time to make this look a little better. We're talking a complete makeover via a custom skin. Now, there's an absolute cornucopia of skins out there for you to choose from, and a lot more from third parties, but the best way to find one is through Kodi's in-app Skin browser. To find this, hit the cog wheel at the top of the app to enter the Settings menu, then go to "Interface Settings" (not "Skin Settings"), select "Skin," then "Estuary," and hit the "Get More" button. This should reveal a drop-down menu with a bunch of skins you can download and try out, all for free [Image C].

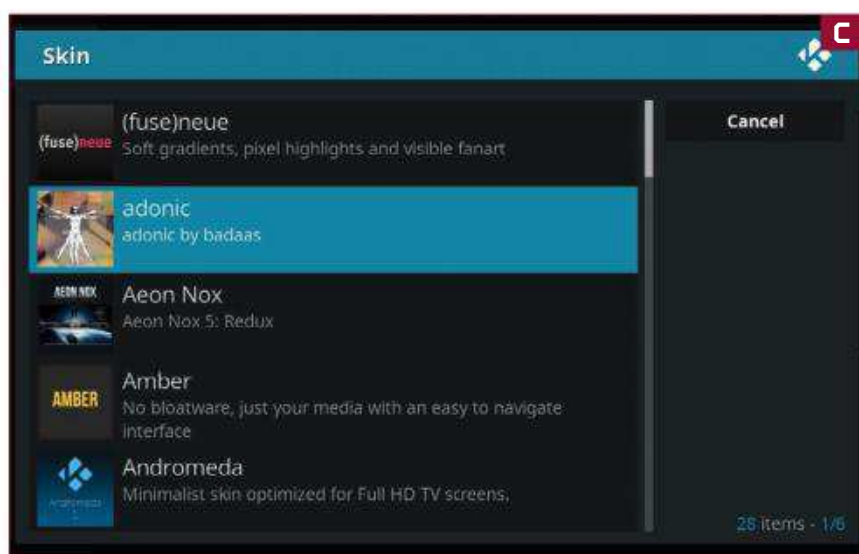
» Each skin is written by a different author, and as such, each one has different layouts and menus from the others, so it can become a little confusing later on. If you do want to return to the default skin, or change skins to something else entirely, always remember that the option to do that is within the "Interface Settings" section of every skin you come across.

5 THE GRID SKIN

There's a ton more skins online; in fact, by Googling "Kodi Skins," you'll likely come up with an army of third-party variants. It's worth bearing in mind, however, that not all of these are Kodi-approved, so approach them with caution. There's also a lot of websites out there trying to cash in on VPN affiliate links. If any of them tells you that you need a VPN for a skin, ignore it; stick with the VPNs you know and trust if you do want one.

» For our tutorial, we're going with the Grid skin. There's a couple of reasons for this: Firstly, we can edit the main menu hub items, so we can add, say, a Steam app launch button, or any other program add-on, for that matter, and





we can reshuffle the rest of them into an order that works for us. It's also one of the better-looking skins out there. Its crisp, modern design keeps the whole system looking fresh, with little to no issue when it comes to ease of use.

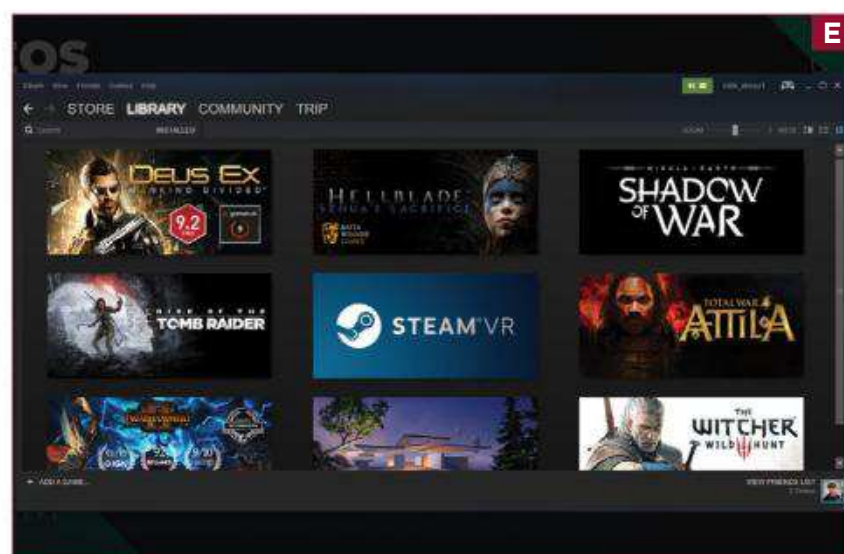
6 BACK TO BASICS

So, you've had a look and downloaded a few skins, found one you like, and installed it. Now what? Well, the next step is to go back to the original skin. Yep, head back to the Estuary skin, by going to "Interface Settings," and changing your skin back to the default version. The reason we're doing this is specifically for this tutorial, and for some consistency between menu settings and our guide. You can do most if not all of what we're about to do in the custom skins anyway, but it's far easier to do it in the default skin, and to explain that, because it has easier access to the menus.

» First thing we're going to do is add any movies we've obtained legally to our movie collection. To do this, go to the "Movies" tab on the main menu, then click "Add Videos"—this opens a source folder. You can now add a path for the folder with all of your movie files in. Hit "Browse," and navigate to your film folder on your PC. Once you've found it, select the "OK" button, hit "OK" again, and Kodi asks you a few basic questions about that directory, before scanning the entire directory. Here you can tell it to rescan the path on Kodi startup, and let it know it whether the films are kept in additional folders, and then categorize the path, too.

7 EVERYTHING ELSE

You can now do the same for every other subsection in Kodi, from TV to Music, Pictures, and Videos, if you so desire. It's a smart way to condense all of your media into a single user-friendly interface, and it's great for showing family and friends your holiday photos quickly and on the fly. There are options to add support for streaming services such as Spotify and Netflix later on



(unfortunately, non-officially supported by Kodi), but we'll cover that a little later.

» If you don't have any media in a certain subcategory, you can choose to hide the entire subsection. However, it's worth noting that this doesn't translate across different skins.

8 SUNSHINE SETTINGS

Right, it's time to set up the weather forecast. This one's fairly simple to do: Head to the "Weather" section of the Kodi interface, hit the button that says "Set Weather Provider," then choose which weather station you want for your forecasts (Yahoo! Weather is our go-to). Hit the "Enter Location" button, then type the name of the nearest city you can find to you.

» Once that's done, it should bring up all the weather forecast details for your area [Image D]. Admittedly, it's not necessarily useful for everyone, but in some skins, it does provide you with weather information permanently fixed to the main display as a scrolling widget, so it's worth having, even if it's just to finish off the skin.

9 INSTALL STEAM

To get Steam working in Kodi, you first need to head back to the Windows desktop, and download and install Steam. Head to <https://store.steampowered.com>, and select the green "Install Steam" button at the top-right. Download Steam, and point it at your C: drive, regardless of where your game libraries are.

» Once it's installed, enter your details, set Steam to "Remember Me," and log in to your account. Then you'll want to change where Steam automatically installs your games. Ideally, you want them going to a drive with plenty of storage space. Click the "Steam" tab in the top-left of the window, then select "Settings" from the drop-down, and click on the "Downloads" tab. Hit the "Steam Library Folders" button at the top of the main window, then "Add Library Folder," and create a new folder where you want to install your games. Right-click that new path, and set it as your "Default Library Folder."

» Now you can download the games you want on your HTPC [Image E]. Local co-op titles and games with controller support are your best bet.

10 INSTALL THIRD-PARTY ADD-ONS

There's always an element of danger when it comes to installing third-party add-ons from repositories or zip files; while the majority are fine, some inevitably have malware embedded in them. We



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recommend you always run an antivirus or antimalware scan on any downloaded third-party zip file before adding it to Kodi, and only download them from a reputable source, such as Github.

» For our Steam launcher, you're going to want to go to Github here (<http://bit.ly/teedubb>), and download the "script.steam.launcher-3.2.2.zip" file.

» Once you're back in Kodi, go to the "Add-ons" main hub, then click the unpacked box in the top-left menu, and click "Install From Zip File." It'll throw up a security warning asking about trusting third-party add-ons, which you'll have to enable in settings, then you can point the path at the zip, and install the add-on directly into Kodi. A notification pops up at the top-right upon completion.

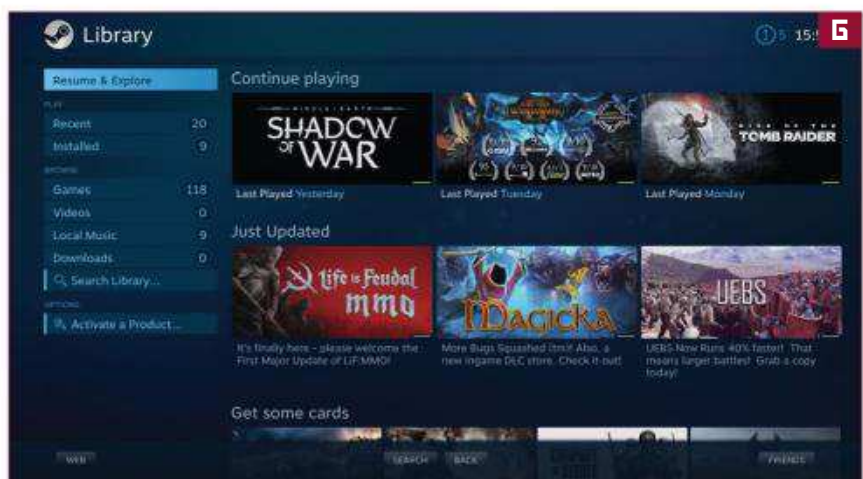
11 BACK TO GRID

Now that's out of the way, it's time to get Steam working as a launchable submenu. To do this, go back to your "Interface Settings," and dive into your skin of choice once more, which in our case is Grid.

» Once it's activated, head to "Skin Settings," then "Menus," then select the "Customize Home Menu and Widgets" link on the right [Image F]. Click the "Add Shortcut" button on the top-right. This should add a link on the left that says "<NONE>." Hover over that with your mouse, and you'll see a little crosshair icon on the right-hand side. Click that, select "Add-on," then "Program," and then select "Steam." This creates a link to Steam's Big Picture Mode on the main menu of your Kodi install. Note that this may be different, depending on the skin you're using, but if you do swap between skins, rest assured that all your settings and configuration will be saved for you as soon as you come back.

12 MENU MANAGEMENT

While you're in this menu, it's a good opportunity to hide any main segments you don't want, and re-order your grid [Image G]. To do this, use the three dots menu indication to the right of the crosshair icon. This should pop up another menu, which enables you to move each category down, rename the label,



change what action Kodi takes upon clicking it, or delete the category entirely.

13 VPNS?

Let's talk about the big elephant in the room, then. If you've reached this far in our guide, you'll have likely browsed the Internet in search of all manner of Kodi add-ons and skins. And you've probably found a fair few websites advocating different VPNs to keep you safe while you browse online.

» Now, there is definitely an argument to be had about using VPNs if you're privacy conscious, especially if you're using third-party add-ons from non-Kodi-approved sources. Fortunately, things such as Steam operate directly through the Steam app—you log in outside of Kodi, and what the launcher does is just that: It launches the Steam desktop app in Big Picture Mode from the desktop, not technically through Kodi.

» If you are looking for a VPN, however, there are two we recommend: ExpressVPN [Image H] and Tunnelbear. Both are easy to use, fairly inexpensive (especially if you're using them across multiple rigs), and trustworthy, in our eyes. Don't worry, we're not throwing a referral link at you, or anything along those lines.

14 THE PERFECT STARTUP

So, you've got Kodi set up how you like it, your basic add-ons are installed, and your media is all in one place—now it's time to streamline the initial boot procedure. And by that we mean auto Kodi startup. There's a few ways you can do this: You can dig up an add-on that does it, or you could just pop a Kodi.exe file into the startup folder in Windows (the far easier solution).

» To do this, go to your Windows desktop, hit the Start menu, and type "Run." Open the Run desktop app, type "shell:startup" and press "OK." This opens your Startup folder. If you enter a program.exe file into this location, Windows starts the program automatically upon login. It's simply a case of finding the kodi.exe file (installed in "C:\Program Files (x86)\Kodi"), and copying and pasting it into the Startup folder.

» You can streamline this process further by hiding all your desktop icons, and setting your taskbar to show on mouseover. For the desktop icons, right-click anywhere on your desktop, hover over the "View" option on the drop-down menu, and uncheck "Show Desktop Icons." For your taskbar, right-click it, hit the "Taskbar Settings" option at the bottom, and check the "Automatically Hide the Taskbar in Desktop Mode" option, and that's it. You now have a super-slick, clean Kodi install on your new HTPC. ⏻

TURN ON, TUNE UP, ROCK OUT

Your PC is a recording studio in waiting;
Phil Iwaniuk shows you how to create it

WE HAVE ALAN TURING to thank for music's long and fruitful relationship with computers. In 1951, he built a device that occupied an entire room at the Computing Machine Laboratory in Manchester, UK, and was capable of playing contemporary favorites "God Save The King," "Baa, Baa, Black Sheep," and "In The Mood." The acetate disc recording was recently restored, and the giggles of the celebrated scientist's colleagues can be heard between the violin-like notes of his device.

Sixty-seven years later, the technology required to write, record, produce, and master an industry-standard banger fits within a PC case. Recording software and hardware has never been cheaper or more accessible, and the Internet has birthed an inexhaustible information resource for budding musicians and producers. In other words, you have little excuse for not trying music production. Mr. Turing's watching, and he doesn't take "Just another round of *Fortnite*" for an answer.

For some, it's a hobby. For others, it's a full-time job. That means the price and quality of equipment and software scales almost infinitely. But the vast majority of us don't need that \$10,000 rack compressor, or a vintage German microphone of the same design that was used on a Beach Boys record. All we need is an audio interface to plug mics and instruments into, a digital audio workstation (DAW) to arrange the recordings within, a good pair of studio monitors, and some software for mixing and mastering. That doesn't have to represent a huge outlay, nor does it have to entail a huge amount of study to get things working.

There is complexity in music production for those who want it, but it's best to lay a solid foundation around the basics, which you can build upon. We'll cover recording techniques, MIDI programming, software choices, and hardware requirements, without the empty jargon or "Peter Gabriel once told me..." anecdotes. This is music production for PC enthusiasts, not former Nickleback roadies.





PC HARDWARE

The good news is that you already own an important part of the setup: a good PC. The better news is that your gaming rig is probably already overqualified for the job, because music production generally isn't as taxing as playing *The Witcher III* at 60fps in 4K. The emphasis is placed on other components, though, so sadly your expensive GPU isn't going to be of much use in this scenario. What's most important when building a music production PC is storage. Gigabyte upon gigabyte of fast, reliable SSD storage. Recording audio takes up space, and that required space increases with recording quality. With that in mind, at least 1TB of SSD storage is generally agreed upon as the foundation of a sensible setup. There's a caveat if you're only intending to use your home studio for exclusively electronic music, though: Because you won't be recording audio, you only need enough space to install your DAW, VSTs, and other incidental software gubbins, and a 500GB SSD should be up to that job. Samsung's ever-impressive 860 Evo drives fit the bill here: \$240 gets you 1TB of lightning-quick storage, while the 500GB model costs \$125.

Next in the music production component hierarchy is your friend and ours, the CPU. It's the real star of the show, modeling sounds in synths, figuring out all the math involved in compression, reverb, delay, and the like, and it keeps track of all your automation. Music software isn't programed to make use of your GPU's processing power, so raw CPU performance is paramount. As with gaming and many other applications, the quandary is in cores versus clock speed. The good news for those in possession of a quad-core CPU or above is that all the major DAWs make use of multiple cores and threads. The bad news is that they don't always do so in the most efficient manner, and won't necessarily scale all the way to eight cores. So, you don't need to go beyond four cores. Clock speed is a more reliable indicator of performance within DAWs and great lumbering synths with more dials than the cockpit of the *Nostromo*, so opting for a 3.5GHz model or higher yields noticeable benefits. On the Intel side, the quad-core 3.8GHz i5-7600K makes a fine candidate at \$230, while AMD's Ryzen quad-core, 3.5GHz R5 1500X offers a real bargain at \$190.

8GB RAM is considered ample for smooth operation of most DAWs. That's a low barrier for entry for most enthusiast PCs in 2018, but don't fall into the trap of thinking that 64GB kit you've been mulling over will improve performance proportionally. The laws of diminishing returns in memory apply just as much to music production as



Home studios tend to expand over time, but a setup like this is by no means required at first.



Finding the sweet spot when miking up an amp takes a lot of patience, and a good ear.



Pop shields prevent spikes in the waveform, and also keep spittle at bay.

they do to video production or gaming—in other words, 16GB is usually overkill. Why's RAM important in the first place? Not least because, as you record, you're creating large audio files, which need to be written to permanent storage, so more RAM prevents the delay between recording and playback. Need to load a lot of plugins and run them simultaneously? RAM picks up the slack again. Once a track's finished, and all these monstrous audio files are rendered out together into a single file, RAM kicks in once more to speed up the file creation. However, it's not going to make anything sound better, and its impact on DAW operation is much less than that of your CPU. Since you only need a good 8GB kit, look for flash deals at your favorite retailers on RAM from reliable manufacturers, such as Corsair, G.Skill, Patriot, and Ballistix.

Do you need anything else specific inside your PC case? Not really. Forget about

soundcards, because your audio interface will circumnavigate any internal models. If you were to treat yourself to an extra piece of PC gear, a second monitor would probably prove the most useful purchase in a home studio setup. This really doesn't need to be capable of impressive color reproduction or crazy resolutions—it's just some additional screen space where you can drag extra programs or keep a browser window open. Old, forgotten panels you upgraded from years ago make ideal candidates for this task, but if you're determined to spend money, look at something like Acer's \$99 G227HQLAbi. It's 21.5 inches of nonsense, 1080p screen.

And now to contradict everything that comes before this sentence: Chances are, your PC is probably already up to the job. If you don't hit the specs mentioned above, go ahead and try running the software mentioned further into the article

anyway. The worst that can happen is some sluggish performance, and that can be easily remedied with just one or two of the recommended upgrades above. With all that said, let's run the numbers on our recommended gear so far.

COMPONENTS	SPEND
1TB Samsung 860 Evo SSD	\$240
Intel Core i5-7600K	\$230
8GB RAM	\$100
TOTAL	\$570

AUDIO HARDWARE

With a muscular music production PC setup whirring away at your desk, the next order of business is to invest in the external hardware that will facilitate your home recording needs. There's another caveat here for EDM folks, the awkward so-and-sos: If you want to make entirely software and sample-based music, you don't need an audio interface, because you won't actually be recording anything. For everyone else, whether you plan to record vocals or instruments through a microphone or via line inputs, an audio interface is required. The name refers to a piece of hardware that takes analog audio inputs (for example, a microphone via XLR), passes that signal through a preamp, and converts it to digital data, which can then be manipulated on your PC. The price range for these starts at around \$50 and never really reaches an upper limit. The legendary Sony Oxford

OXF-R3 console costs \$1 million, and many industry standard mixing desks carry a price tag in the region of \$50,000. You don't need one of these.

What you do need is an interface with some inputs for your microphones and instruments, a USB output to your PC, and connections to hook up to some studio monitors. You don't need to spend more than around \$250 to achieve this, and Focusrite's best-selling Scarlett range is a particularly good place to start looking. The Scarlett 2i2 Studio 2nd Gen is a fantastic entry point, comprising not just a two-input audio interface, but also a mic and studio headphones. Focusrite has a good reputation for rolling out regular driver updates, and its Scarlett models are generally low on input lag, which is crucial for recording precise instrumental performances (although CPU performance has a major bearing on this, too). The two inputs on the 2i2 are compatible with both XLR and 1/4-inch audio jack. Microphones tend to feature XLR jacks, whereas line instruments, such as guitars and basses, use the 1/4-inch jack. Having both input types on your interface saves on having to

Focusrite's Scarlett 2i2 bundle offers all the essentials on a budget.



buy any messy adapters later on, and having two of them means that you can record multiple performances at once—vocals and guitar, for example. The headphones and condenser mic bundled with the 2i2 aren't industry-standard, but for a beginner, they're more than fit for purpose.

Are there alternatives? Of course. The Audient ID4 is a really compact and well-built two-input interface from a company with serious kudos for its pro-grade mixing desks, priced at \$199. For those seeking more inputs, the Komplete Audio 6 from Native Instruments brings a lot to the party for \$180—not least six inputs and a flashy design. Nevertheless, the Focusrite Scarlett 2i2 gets the nod for sheer value for money and reliability.

The only other essential you'll need in terms of audio hardware—other than mics and instruments to record with, obviously—is a good pair of studio monitors or headphones. A very common mistake people fall into here is thinking that their expensive gaming headset or audiophile headphones will do the job—they

HOW TO RECORD MICS AND INSTRUMENTS



To record vocals, drums, guitars, bass, and other instruments with an audio jack input, you need an audio interface. That's a fancy name for a box that receives analog inputs and translates them into digital data for your PC via a USB cable. Let's start with recording sound via a microphone.

With the mic plugged in and positioned, open up your DAW, and select an audio track so that it's listening to the input your mic's plugged into. Now "arm" it by pressing the red recording button, and make a noise into the mic. If you can see the levels coming into your DAW, the signal chain is set up correctly, and you're ready to record. Some mics require phantom (additional) power, which is a matter of pressing the "+48V" button on your audio interface. Do check this on the specs before hitting the button, though. For instruments such as electric guitars and basses, the process is the same—just plug it into the audio interface, and follow the signal chain through to your DAW.

You can also use a mic to record instruments by positioning them at an amplifier's speaker head, but some are too sensitive to deal with such high volumes. The industry standard mic for this purpose is the Shure SM57, and it costs \$90. In mic, terms, that's nothing. However, it's

Recording a drum kit well requires several mics, so stick to MIDI programming for percussion.



useless for recording vocals, so you need one as well as, rather than instead of, a more sensitive, larger diaphragm mic.

Mics pick up room sound as well as your voice or amp, so if you want things to sound tight, record in a small, carpeted room, with few reflective surfaces. The old hip hop "two mattresses and a sheet" vocal booth works wonders. This isn't necessary for amps, where mic positioning has a greater bearing on sound than room materials.



won't. Consumer audio is about making things sound as nice as possible, and manufacturers achieve that by boosting certain frequencies in a speaker or headphone's voicing. Pro audio is about making things sound as they are, which means an absolutely flat EQ. Ergo: Your Bose QuietComforts just aren't going to cut it while you're mixing, because they're telling you there's more bass than is actually there. When someone else listens to your mastered track, it'll sound thin. For true sound reproduction and the best mixing experience, you need a pair of studio monitors. Monitors come in active and passive variants, the latter requiring a preamp to power the speakers themselves. For a budget home studio, an active pair such as Yamaha's HS5s are ideal. At \$270, they're well built and offer great sound.

While monitors are best when you're mixing, there are plenty of times when you need to contain sound, not blare it out. When recording vocals and instruments, headphones are a must. If you go down the route of the Focusrite bundle, you already have that problem taken care of, but for everyone else, there's the BeyerDynamic DT 770s. These are one of a rare few pieces of studio-quality gear that remain affordable to all, usually priced at around \$120. They're comfortable, beautifully balanced, and they'll last a thousand years.

Moving on to mics now, and another such affordably priced gem: Shure's SM57



Reaper doesn't look very friendly or inviting, but it isn't nearly as scary as it first appears.

condenser mic. Even if you do go with the Focusrite bundle, this one's worth picking up for \$90. Why? Because it's the industry standard for recording guitar and bass amplifiers, and even holds its own with snare drums—anything oppressively loud, in other words. The bundled Focusrite CM25 condenser mic isn't designed for such high volume levels, because it's intended as a vocal microphone. And vocal mics are a very different beast, designed to pick up on the almost inaudible subtleties of the human voice, rather than the almost deafening presence of a guitar amp. Looking beyond the bundle, Rode's NT1-A sells for under \$150, and always

captures good vocal recordings, regardless of the singer or style. If you're serious about recording acoustic guitar, buy two of these, and position one at the sound hole about eight inches back, and another level with the twelfth fret, positioned slightly further back.

As you can see, there's always a lot of potential to buy "just one more thing," and end up with a studio bigger than that of Quincy Jones. Without getting carried away, there's a couple more incidental audio hardware purchases to cover before we add up the damage. Pop shields aren't essential for vocal recordings, but they do make a big difference to the recording

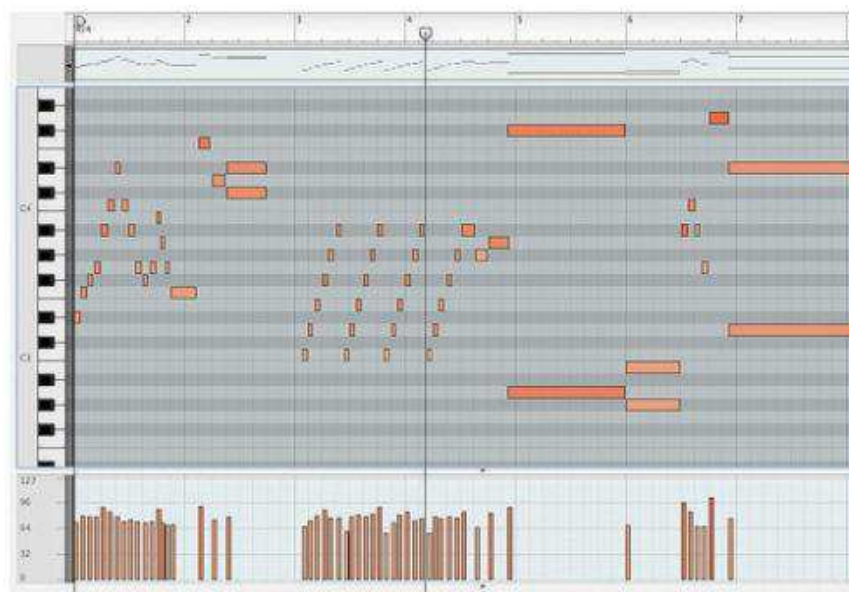
HOW TO PROGRAM MIDI SOUNDS



For key instruments, drums, and EDM sounds, MIDI is your best friend. It stands for "musical instrument digital interface," but in practical terms, that's neither here nor there, is it? What you need to know is that it enables you to draw notes into a sequencer, and those notes can be applied to any number of virtual instruments.

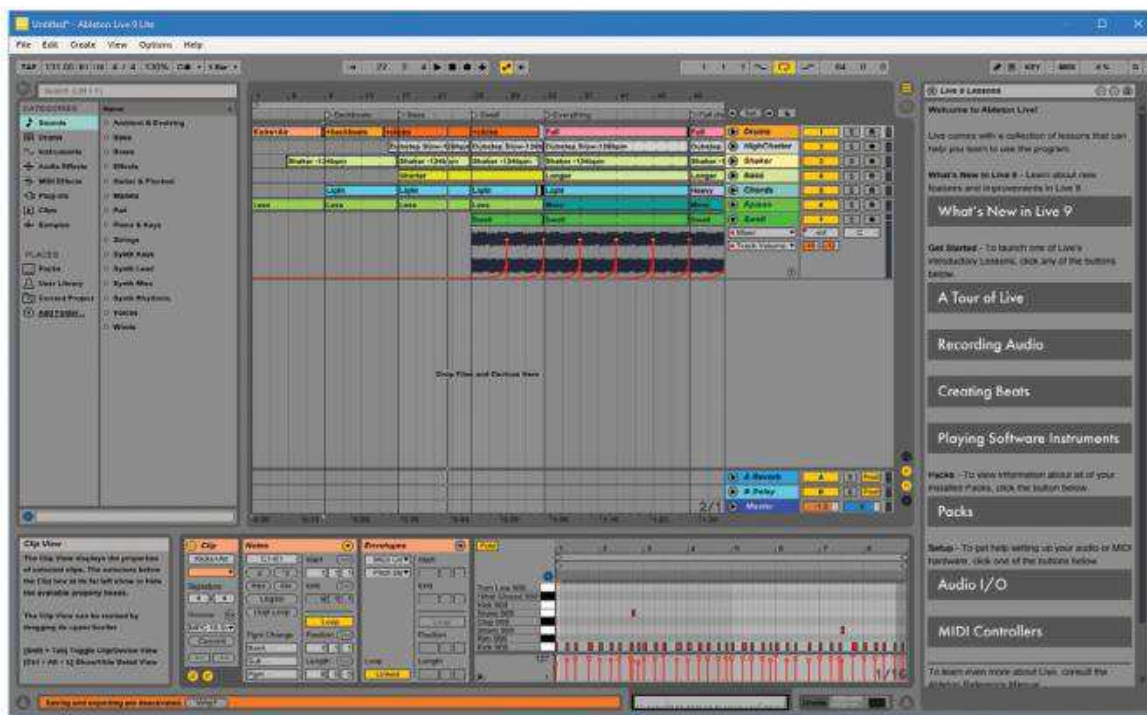
Many producers eschew instruments altogether and create entire songs with MIDI, using either a MIDI controller to program the notes, or doing it the harder way with a mouse, note by note. MIDI controllers, either in a traditional keyboard layout or nu-school grids of buttons, can be bought for less than \$100, and take a lot of the chore away from programming. If you already have mad keyboard or piano skills, go ahead and consider one essential. From devising chords to noodling away at melodies, playing the part is much easier than programming it with a mouse.

However you choose to program, there are a few pointers you should keep in mind while you write: Editing the velocity (how hard the note's played) adds a human touch to MIDI parts, so pay attention to this if your track's sounding a bit robotic. At the other extreme, if you're playing the parts on a controller, and they're sounding messy, make use of the quantize function in your DAW. This snaps your programmed notes to a timing grid and irons out any temporal mistakes,



A synth or virtual instrument determines the voicing of MIDI notes.

but you need to choose the right setting for the notes to arrange themselves as desired. If you don't know your music theory, and aren't sure whether the part's written in sixteenth notes or eighths, just try each setting out until one sounds right. Programming percussion and melodic instruments both adhere to these principles, for the record.



Ableton has a lot more live DJing functionality than other DAWs, hence the “Live” moniker.

quality. So-called because they filter out the harsh “pop” sounds from plosives as they’re being sung, preventing spikes in the waveform, they’re available for around \$10. Last but not least, the most unglamorous purchase in any home studio: the mic stand. Most people only need one, but if you want to record an acoustic guitar in stereo, or wish to blend a vocal performance captured through two mics—that’s advanced-level stuff for this guide—buy two. Don’t spend more than \$40 per stand. It isn’t big, and it isn’t clever.

COMPONENTS	SPEND
Focusrite Scarlett 2i2 Studio Bundle	\$250
Pop shield	\$10
Mic stand	\$20
TOTAL	\$280

AUDIO SOFTWARE

Thus far, you’ve got everything required on the hardware side to send an audio signal through to your PC. This is the point at which

software gets involved. With some degree of inevitability, it’s also where things get a little complicated.

The first order of business is to choose a DAW. The big names in the field are Pro Tools, Reaper, Ableton, Cubase, and FL Studio, among others. Think of these as being the Photoshop, or Premiere Pro, of the music production world. They’re where you record sounds on to tracks, write MIDI data, build synths, load VSTs, mix tracks, apply effects, and master them. They’re the beating heart of your recording studio. Fortunately, their user interfaces are broadly similar, and will be at least faintly familiar to anyone who’s worked with video-editing software before. Unfortunately, that doesn’t mean they can’t still seem unfathomable at first.

Pro Tools costs \$2,500, and is intended for professional studio engineers—you don’t need it, and it won’t make your music sound magically better. Let’s discount it. At the other extreme, Reaper is totally free, and features a lot of the same functionality as Pro Tools. And we’re not sure if we mentioned this already, but it’s *totally free*. Among those significant advantages, its UI is laid out in a pretty similar way to Pro Tools, so if you do end up progressing to those lofty professional heights, you’ll already know your way around to an extent.

There’s another free option available if you went with the Focusrite Scarlett bundle on the hardware front: Ableton Live Lite

HOW TO MIX YOUR TRACKS



Writing and recording the instrument parts is only half the battle. Making those parts sound good together, and making the final song sing out on car stereos, smartphones, radios, and Bluetooth speakers, comes down to the mix.

Starting at complexity level one, consider the volume and pan of each track. In the traditional rock band setup, vocals and bass live in the middle of the mix, while guitars and other instruments are panned either side, and drums live across the full stereo spread. In EDM, similar principles apply: vocals and bass in the middle, other parts either side. Adjust the pan on your tracks until you can hear them all distinctly, then make adjustments in volume so it sounds like each part has breathing space, or to put it another way, so that parts don’t sound like they’re competing to be heard. Weak vocal or instrumental recordings can be hidden in the mix by lowering the volume, but that’s a poor substitution for getting a good track down in the first place.

Complexity level two is compression. A compressor sets the minimum and maximum volume of a track, and can be used to tighten up an individual part and the entire song. Every chart song you hear has some level of compression applied to every track, then the master track, and then another during the mastering process. At a bare minimum, they should be applied to vocals and any instruments with



A little goes a long way when it comes to applying effects to your tracks.

a wide dynamic range, such as a guitar played softly in the verse, then strummed hard in the chorus.

Complexity level three—ready?—comes with auxiliary tracks. Place effects such as reverb and delay on aux tracks, then send an instrument track to it, and thereby achieve a mix of dry and effect-laden sound. Easy, no?



Old-school palaces like this do still exist, but they're increasingly on the retreat to home setups.

is included with several other programs. Ableton's great: At one and the same time, it's a fantastic live DJing suite and a straight-laced studio DAW. That means its UI is slightly different from its contemporaries, but it shouldn't be discounted on those grounds. You won't notice the Lite version's

constraints at beginner level—it does everything you need it to do.

Once you settle on a DAW—and really, it's a personal thing, like mouse sensitivity and search history—the next software purchases to turn your attention to are virtual instruments (VSTs). If you're looking

to make EDM, these are your bread and butter, and you should thus set aside some financial backing accordingly. For those looking to make music primarily through recording instruments, VSTs will feature little, if at all, in your mix. It might be that you buy a program such as Superior

HOW TO LEARN FROM THE PROS



You'll get the basics from this article, but to take your home recording skills to the next level, at some point you'll turn to video tutorials on YouTube. And it's great that such a wealth of information from so many different voices is at your fingertips. But it's also a double-edged sword.

If the tutorial you're watching recommends a particular VST or plugin, make sure you're not watching a piece of sponsored content. This happens a lot. It's a similar story if the content creator is selling a bunch of instrument presets—find another tutorial. There are plenty of knowledgeable studio engineers and producers on YouTube, so you don't need to try to glean information from covert advertisements.

Find a producer or engineer who makes the kind of music you endeavor to make, or achieves a particular sound you're striving for. Most importantly, make sure they're using the same DAW. There's no point learning how to set up a sidechain compressor in Pro Tools if you're using Logic Pro. Don't worry if they're using slightly different VSTs or microphones, though: You won't achieve the exact same sound as them, but you'll learn a lot from copying the way they do things, and hearing the effect it has on your projects. If they offer a step-by-step project for you to



If someone's shilling software or gear, don't follow their tutorials.

follow, all the better. Keep mindful, though, that there's rarely just one "correct" way to do things in music production. The tutorial you're watching shows you one way to do things, and offers the comfort blanket of an assuredly good sound. Great producers build on this know-how, and develop their own techniques, creating a sound that others will want to replicate. Who knows—maybe one day you'll be the one uploading tutorials.



Maybe one day. First, learn the basics using free software and a few reasonably priced hardware essentials.

Drummer 3 (\$300, Toontrack) to program MIDI drums, and achieve a realistic studio recording drum sound, instead of buying four or five microphones, and trying to reach that same polished sound the hard way. The same goes for bass VSTs, because—hand on heart—who really wants to have to deal with a human bassist?

It's hard to recommend certain VSTs for everyone, because their use is deeply tied to the genre and sound you're looking for. However, the aforementioned Superior Drummer is the Rolls-Royce of drum VSTs, and Komplete (\$500, Native Instruments) offers sample libraries from every instrument you can think of, right down to the ones only used for game show tie-break questions. Many VSTs contain standalone versions, which can be loaded and operated outside of a DAW, but know that in order to record them, you need to load the DAW first, and assign the VST to a particular track. VSTs are all kept in a particular folder, so you just need to tell your DAW where to find them in the preferences menu.

Last, but certainly not least in software terms, a good mixing and mastering suite is essential. These comprise compressors, EQs, reverbs, delays, limiters, and other effects, and they're applied to tracks after the audio has been recorded, or the MIDI data written. Think of them like sonic glue, bonding each instrument to the next. The Waves Gold Essential Mix & Master bundle (\$150, Waves) offers everything you need in this regard, and once again, it's one of

the less expensive studio components you'll find professionals using. However, as with VSTs and even DAWs, free options are worth investigating, too. KVR Audio has dozens of plugins going gratis at www.kvraudio.com/plugins, and they're all worth experimenting with. Even if you don't end up using them on your track, observing the effect that a five-band EQ or a spring reverb has on the sound is worth it in the long run.

COMPONENTS	SPEND
Reaper/Ableton Live Lite	\$0
VSTs	\$0-\$800
Plugins	\$0-\$150
TOTAL	\$0-\$950

TROUBLESHOOTING

Congratulations, you've put together a home studio. Now the fun begins.

Armed with a suite of software and hardware you're unfamiliar with, the potential for snags, snafus, hiccups, and monitor-smashing fits of rage is enormous. So, let's address the problems you're likely to encounter.

By far the most common is being unable to get a signal in your DAW. Your instrument is plugged in, you're playing it for all it's worth, and your PC just doesn't want to hear it. What gives? There's no simple answer, but check the following. Is your instrument's volume turned up? Is it plugged into the audio interface properly? Is the volume

turned up on that, too? Is it set to a line or mic? And is the audio interface correctly plugged into your PC and studio monitors, both powered on and turned up?

If the answer to all of those questions is yes, it's time to examine how things are set up on the software side. Is your audio interface correctly set up within your DAW? Look for the inputs and outputs in your system preferences, and ensure they're set to your audio interface. Do you have the latest drivers installed? (Yes, that old chestnut.) Is the track set to record? Are you seeing levels come through into your DAW? If your mic or instrument is plugged into input two, is the track in your DAW also set to input two?

If the answer is still yes, it's time to head to the message boards. Someone's probably had a similar problem using your equipment, and if they haven't, posting a quick question on the manufacturer forums or the charmingly named GearsLutz will usually yield useful responses.

Let's conclude by once again considering Alan Turing. He may not have had to worry about driver incompatibility in 1951, but he managed a pretty serviceable rendition of the British national anthem using a computerized device he built from scratch. If that doesn't inspire you, your soul is dormant. You'll encounter problems along the way to recording your first song, and your tenth, and your hundredth. But you'll learn from every one of them. Play us out, Mr. Turing: "Baa, Baa...." 🐑

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TECH PORN



I VOLUME DIAL

There's nothing like some classy lighting. The giant dial at the top both controls the volume and displays audio levels with a ring of circular light, decreasing and increasing around its edge. Of course, you could just use the remote instead.

2

ADVANCED DESIGN

From the premium Burr-Brown DAC to the DSP processor, capable of calculating an incredible 2.7 billion 40-bit calculations a second, this is one of the most advanced all-in-one audio solutions on the market.

Naim Uniti Atom

A GOOD HOME THEATER IS about more than just impressive visuals. It's an entire experience. Something to be savored and enjoyed. A combination of many elements coming together to provide a sensorially evocative event that captivates the mind and transports you away from the rigors and chores of everyday life. Visuals are just one part of that symphony of ecstasy.

Naim's Uniti Atom is the final piece in our home theater puzzle. It's a highly advanced all-in-one solution that incorporates a phenomenal array of technologies in a stylish anodized box of aural wonder.

Don't believe us? Well, at its base level, it's a high-quality DAC and speaker amplifier. It supports Bluetooth, 2.4/5GHz Wi-Fi connectivity, and Gigabit Ethernet, has dual USB ports, packs triple digital inputs (two TOSLink, one S/PDIF), the usual array of analog inputs, preamp and speaker outputs, and support for HDMI. Couple all that with the fully functioning remote, mobile APP, wireless multi-room support, Android Chromecast, Apple Airplay, Spotify, Tidal, and iRadio support, an embedded 5-inch full-color LCD display, and the opportunity to expand the built-in storage with a separate NAS unit for your own music and media, and well, what's more to be said? It's incredible. And pricey, oh so pricey. —ZAK STOREY

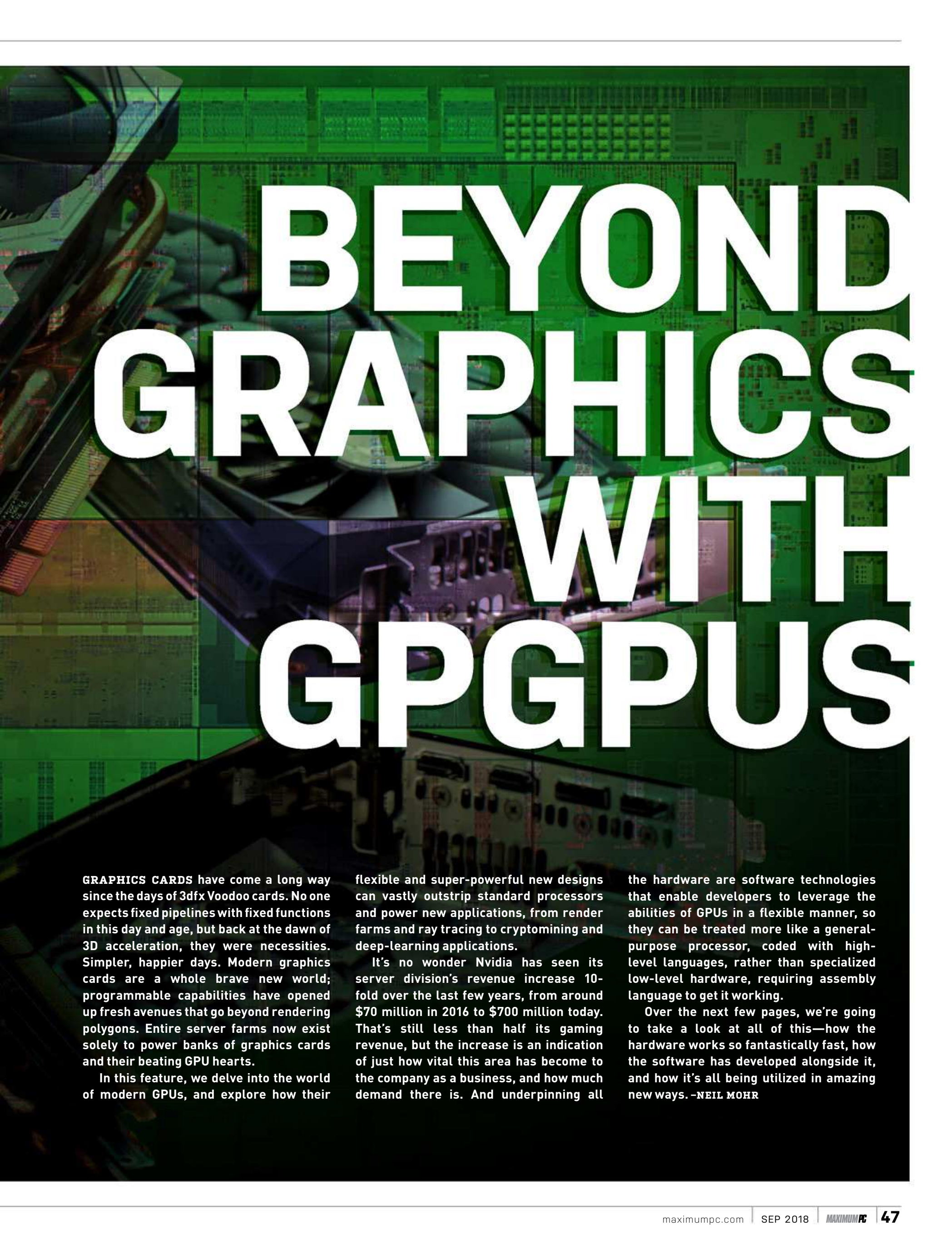
3

LCD DISPLAY

From album art to menus and app support, the LCD display is an awesome addition to this DAC amp's arsenal of very many features. It even has a proximity sensor, which activates only when you approach it. Unfortunately, it isn't touchscreen, but if we're honest, keeping fingerprints off it is probably a good thing.



Your GPU can do so much more than render Lara Croft at 120fps—the power struggle over the heart of your graphics card is powering a multi-billion-dollar industry



BEYOND GRAPHICS WITH GPUS

GRAPHICS CARDS have come a long way since the days of 3dfx Voodoo cards. No one expects fixed pipelines with fixed functions in this day and age, but back at the dawn of 3D acceleration, they were necessities. Simpler, happier days. Modern graphics cards are a whole brave new world; programmable capabilities have opened up fresh avenues that go beyond rendering polygons. Entire server farms now exist solely to power banks of graphics cards and their beating GPU hearts.

In this feature, we delve into the world of modern GPUs, and explore how their

flexible and super-powerful new designs can vastly outstrip standard processors and power new applications, from render farms and ray tracing to cryptomining and deep-learning applications.

It's no wonder Nvidia has seen its server division's revenue increase 10-fold over the last few years, from around \$70 million in 2016 to \$700 million today. That's still less than half its gaming revenue, but the increase is an indication of just how vital this area has become to the company as a business, and how much demand there is. And underpinning all

the hardware are software technologies that enable developers to leverage the abilities of GPUs in a flexible manner, so they can be treated more like a general-purpose processor, coded with high-level languages, rather than specialized low-level hardware, requiring assembly language to get it working.

Over the next few pages, we're going to take a look at all of this—how the hardware works so fantastically fast, how the software has developed alongside it, and how it's all being utilized in amazing new ways. —NEIL MOHR



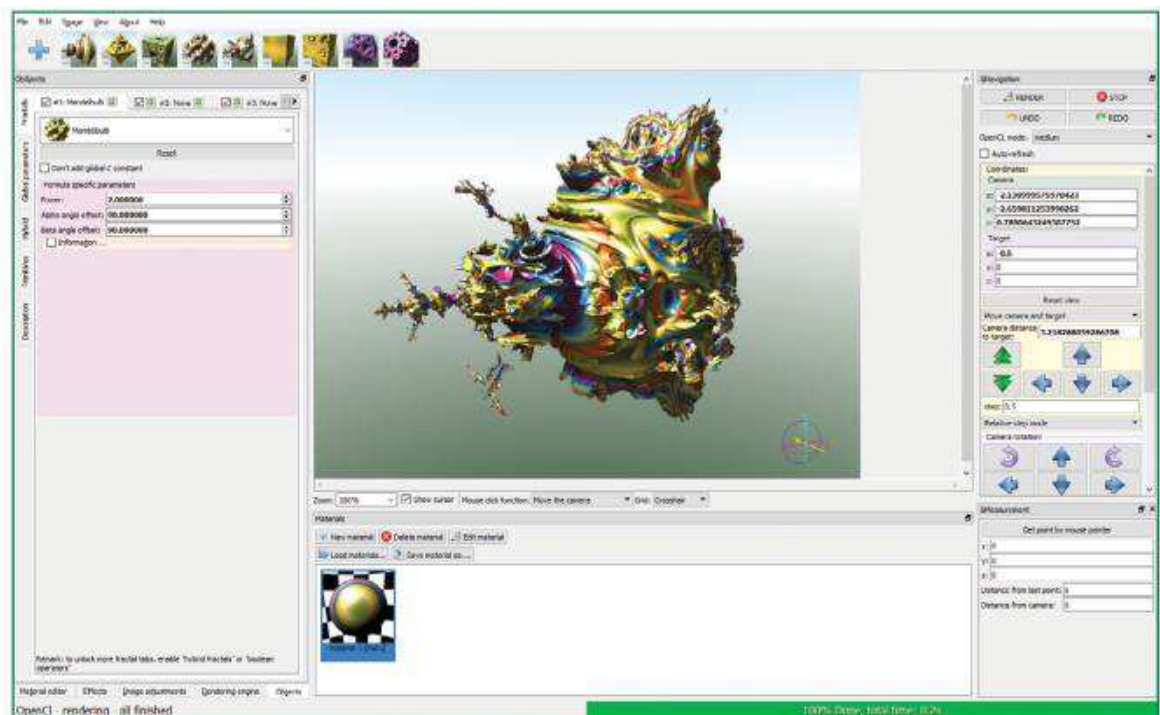
LET'S START WITH the hardware. What turned those single-use, fixed-pipeline, fixed-function graphics cards of the past into the GPGPU (general-purpose graphics processing unit) compute beasts of today? The simple answer is shaders. It's not the only answer, of course—alongside the development of shader hardware, process technology and therefore the complexity of graphics card architecture continued to increase exponentially. It also helped that there was a massive demand for the new technology, and in new areas.

As a rough outline, the GeForce 256 (1999) had 17 million transistors on a 220nm process, and the GeForce 2 (2000) had 25 million transistors on a 180nm process; both were non-shader DirectX 7.0 parts. The DirectX 8.0 GeForce 3 (2001) doubled this transistor count to 57 million, despite being slower than the GeForce 2 Ultra at times. We'll skip the GeForce 4, as it actually reduced its transistor count, ruining our narrative. The DirectX 9.0 GeForce FX (2003, so historically GeForce 5) jumped the transistor count massively to 135 million, and this path continues to today's multi-billion transistor cards—sheesh. Moore's Law: No real surprise, right?

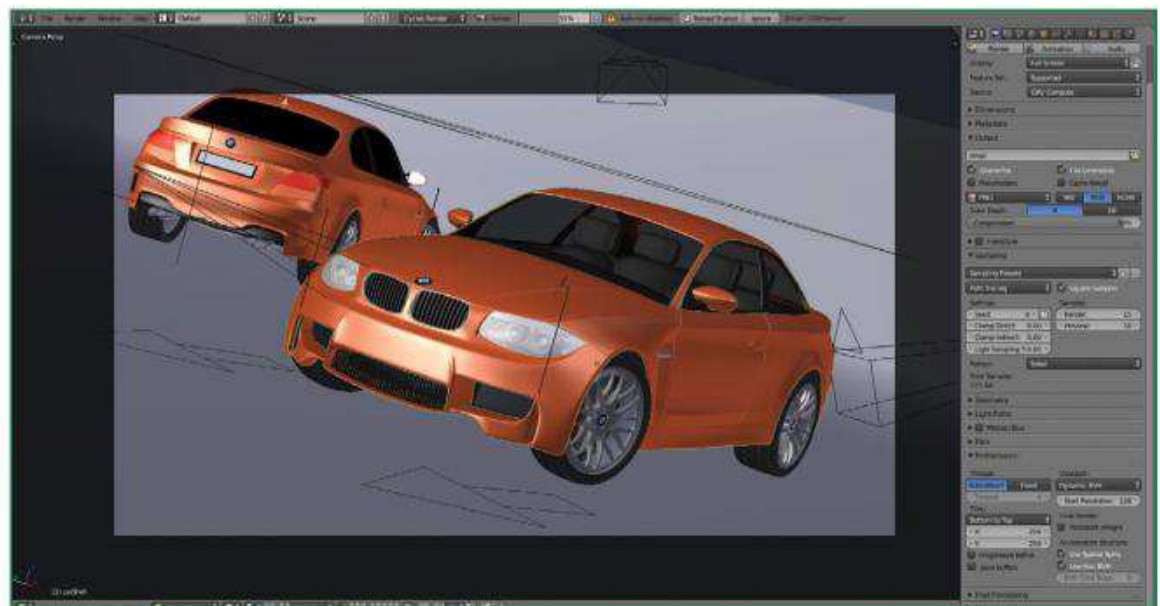
So, what are all those transistors doing? As you'll probably be aware, a shader is effectively a tiny, limited program that can process certain types of data stored by the graphics card. We're not here to talk about how the graphics pipeline works, or indeed graphics card architecture, so we're going to gloss over this to a large degree, but in order to understand the capabilities and limitations of a GPGPU, it's going to be handy to know a little about shaders.

DirectX 8.0 (2000) is when shader technology landed for consumers—cast your mind back to the GeForce 3 and ATI Radeon 8500. Pixel and vertex shaders were implemented as separate units and were super-limited. The v1.1 pixel shader was limited to a program length of 12 instructions, with only 13 address and 8 color operations to choose from. The vertex shader had no branching, and a maximum 128-instruction program length. By the time we reached DirectX 9.0c (2005, Radeon X1x00, and GeForce 6) the specification allowed for 65,536 executed instructions, dynamic branch control, and plenty more besides with Shader Model 3.0.

Even at this stage, the GPU could still be thought of as a fixed pipeline; the clever stuff was starting to happen inside those standalone pixel and vertex shaders, but they could still only really be used for one job. However, the potential was shining through. As an aside, just consider that the original ARM instruction set—which uses a Reduced Instruction Set Computer



Generating fractals is a cakewalk for GPGPUs.



Ray tracing is ripe for a bit of GPGPU acceleration, and Blender is available for all.

Hash Suite 3.4 [64 Bits] [Free]

Main View Params Hardware Reports Downloader Rules Purchase CPU: 3/4 GPU: 1/1 Style About

Start Stop Resume Attack Format

Charset Phrases Rate: 35.9M Time: 00:00:05 Keys Tested: 190,526,464

Quick benchmark will finish in 5 min (spending 5 sec in each attack).

Processor Name	Frequency	L1	L2	L3	Ram	Other Information
Intel Core i5-2500K	3.30GHz	64KB	256KB	6MB	16GB DDR3-1600	Windows 10 Professional 64-bit
GeForce GTX 950	1.41GHz	96KB	1MB	0KB	2GB GDDR5-3510	Driver 398.11

Format	Threads	1	10	100	1000	10000	65536	100000	1000000
LM	4	247M	238M	226M	213M				
NTLM	4	4.36G	3.97G	2.73G	2.61G				
Raw-MD5	4	196M	193M	193M	0				
Raw-SHA1	4	11.9G	5.90G	5.87G	5.74G				
Raw-SHA256	4	131M	130M	130M	129M				
Raw-SHA512	4	5.80G	4.37G	4.37G	4.29G				
DCC	4	72.3M	72.1M	71.5M	71.1M				
SSHA	4	1.97G	1.96G	1.95G	1.92G				
MD5CRYPT	4	36.4M	36.2M	36.2M	36.0M				
DCC2	4	668M	670M	682M					
WPA-PSK	4	12.1M	12.1M	12.0M					
BCRYPT	4	241M	240M	239M					
		1	4	16	64				
	4	117M	52.0M	16.3M					
	GPU	2.79G	1.25G	310M					
	4	61.7M	16.6M	4.23M					
	GPU	1.70G	428M	107M					
	4	142K	35.5K	8.79K					
	GPU	2.95M	736K	185K					
	4	3.87K	960	241					
	GPU	73.4K	18.1K	4.53K					
	4	4.79K	1.19K	298					
	GPU	90.6K	22.7K	5.71K					
	4	3.07K	769	191					
	GPU	3.19K	797	199					

View saved benchmark

Cracking ended. Found: 0 Total: 0 Found: 0%

Boring, repetitive math is the bread and butter of a GPGPU.

architecture—had around 22 machine code instructions (plus eight pseudo operations), which was enough to power a full desktop computer. The potential of GPGPU, even if the instruction set is limited to, say, just 12 instructions, is there in its vast parallelization, execution speeds, and fast local memory store.

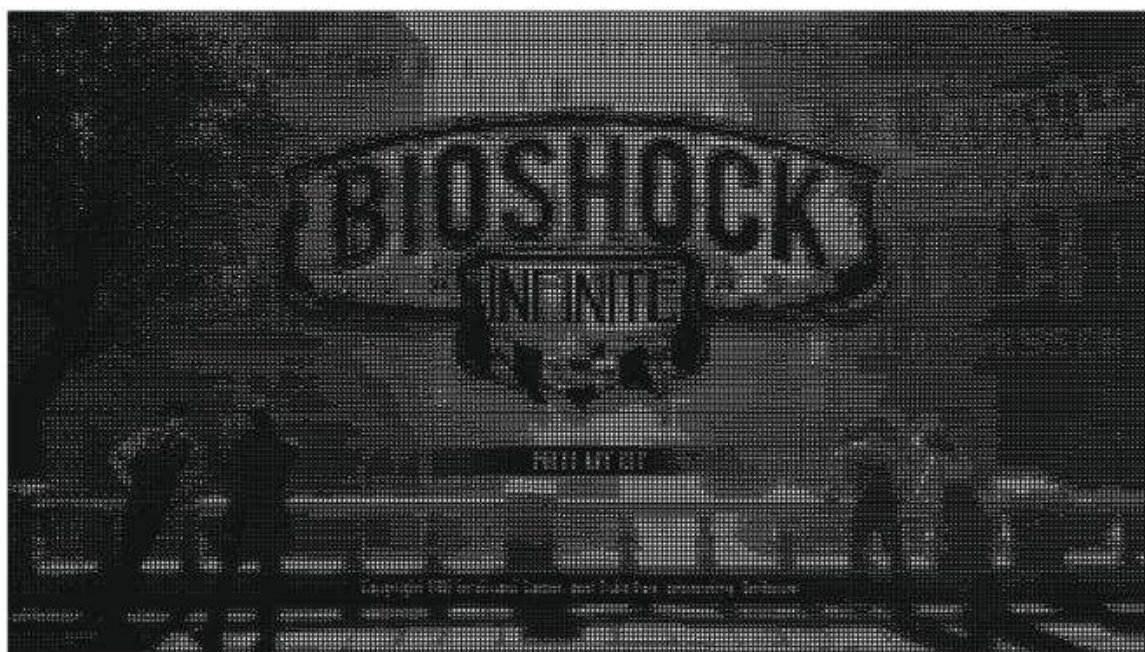
With DirectX 10 (2007), unified shaders became a reality. Technology had moved on enough that it was possible to implement a single, sufficiently flexible compute architecture that could handle pixel, vertex, and geometry shading in one. For example, the GeForce 8800 GTX, launched at the end of 2006, had almost 700 million transistors, and supported DirectX 10.

By this point, research into utilizing GPGPU capabilities was starting to return practical solutions. The first stabs at utilizing the matrix capabilities of a GPU had begun back in 2001, with the first hardware implementations of shaders available at the time. Around 2005, the first practical use that ran faster on a GPU than a CPU was widely available—it was a matrix operation called LU factorization.

DirectX 11 was released as part of Windows 7 in 2009, although technical previews were available from mid-2008. From our point of view, the interesting inclusion was compute shaders, a new specification designed for non-graphical applications to access and use the GPU resources.

As we've alluded to, when shaders first appeared in hardware, they were simple enough that developers were willing to hand-write routines in assembly code for them. Even so, that's far from ideal, and as the complexity of the hardware shader implementations increased, so did the need for software abstraction, which is the fancy way of saying that we needed high-level language support.

First to the API party was Nvidia, with its canny CUDA, released to the public in June 2007. It's possible that your only encounter with CUDA is in connection with the other Nvidia technology, PhysX—remember when you could buy a separate add-in card to speed up your game's physics? While PhysX started as its own technology, GPGPU capabilities swallowed it up—that's just one example of a task that's become GPGPU-



WHAT'S A SHADER?

 A shader is a small program that is run within the GPU's pipeline and manipulates either individual pixels or the geometry in the world in some way. The term comes from shaders' first implementations, which were for shading algorithms, such as the Phong shader to produce smooth images.

There are effectively two distinctive types of shaders: pixel (or "fragment" in OpenGL/Vulkan parlance) shaders and vertex shaders. Pixel shaders work at the end of the pipeline, and their output is an individual pixel's RGB and Alpha value.

What we're calling vertex shaders work on manipulating point vertices of models (three vertices make a triangle) for lighting and warping. Other shaders—geometry, tessellation (fixed function), hull, domain—are all about manipulating geometry within the world. Importantly, shaders are able to process basic input and output back to shared memory, called Stream Output. In the context of graphics, Stream Output enables the GPU to create and animate particle systems without CPU intervention.

With a GPGPU, shaders become the programmable processors of the GPU. Texture units are the read-only memory interface, and the output frame buffer is the write-only memory interface. The basic operations of a shader and the limited input mean that GPGPU excels when there is a large dataset that requires repetitive processing with minimal dependency between data elements.

accelerated. CUDA largely started with one smart chap called Ian Buck, whom Nvidia went on to employ as director of its GPGPU division. At Stanford University, he'd been developing a PhD project called BrookGPU, which was defining a language to program GPUs—oddly enough, this became the basis of OpenCL.

At Nvidia, he took the chance to revisit Brook, and tackle its limitations. The key one being restricted memory access patterns. The Nvidia C for CUDA extensions threw away those limitations, and provided

a huge pool of threads that could access the GPU memory any way the coder wanted, with a full implementation of C's language semantics. CUDA provides a full development toolkit for programming Nvidia's CUDA cores, including a compiler, debugger, and libraries. It supports C, Fortran for science projects, Java, and Python. It also offers APIs for other GPGPU frameworks, such as OpenCL and Microsoft's DirectCompute.

Nvidia really powered ahead in the market, and was the go-to technology in the



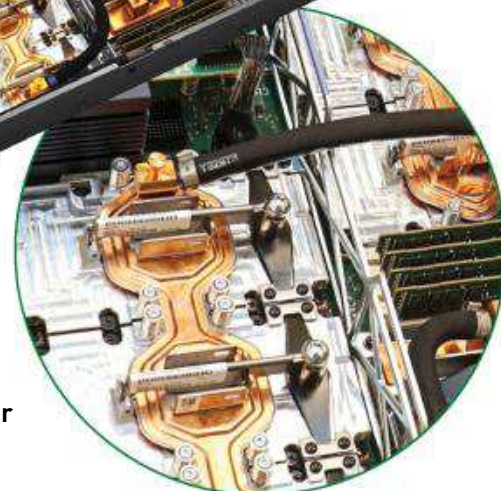
While PhysX started as its own technology, GPGPU capabilities swallowed it up.

In a small warehouse lives 3 exaops of computing power. Unbelievable.



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This is what the inside of a modern deep-learning supercomputer node looks like. Spot the Tesla V100s!



THAT'S SUPER!

 The USA has reclaimed the number one spot for the world's fastest supercomputer, a position that China had held on to since 2012 with its 10-million RISC core, 93-teraflop Sunway TaihuLight. At the heart of each of the 4,600 servers powering the Oak Ridge Summit system are two 22-core IBM Power9 processors, and six Nvidia Tesla V100 GPUs. It's this combination that pushes its processing capabilities to a mind-blowing 200 petaflops—that's over 20 times the power of the Sunway.

What Summit represents is the sea change in direction of high-performance computing toward AI-based processing. AI often uses vast training models and datasets that need to be repetitively processed at high speed. The Summit, with its peak half-precision speed of 3 billion billion operations per second, represents 3 exaops of AI—if everyone on Earth did one calculation per second, it would take 15 years to do what Summit can do in one second.

GPUs are ideal for these modern loads—for example, visual recognition training models that have the job of, say, recognizing a dog. Processing image data is perfect for GPU systems, designed to store textures at incredible speed, while a nice side effect of moving loads to GPUs is a reduction in the total number of servers a high-performance computing installation requires.

It's this change of direction in the high-performance data centers that's likely behind the announced new GPU from Intel, slated for release in 2020, plus the Intel Nervana Neural Network (NNP) deep-learning processor coming in 2019. Intel does currently have its Xeon Phi many x86 core add-in boards, but they're many times slower than Nvidia Tesla.

industry when it came to GPGPU compute power. Being first to market with its own top-flight implementation of a parallel computing platform really gave Nvidia a head start over everyone else—it's a strategy at which Nvidia excels.

In contrast, there's OpenCL (Open Computing Language). This is the open industry standard for parallel computing that was set up by Apple—oddly enough, at Apple's 2018 developer conference, the company announced it will be dropping support for OpenGL and OpenCL on all Apple OSes—and is supported by everyone (bar Apple now), including Nvidia. Of more direct interest to *Maximum PC* readers is the fact that it's AMD's choice of platform for its stream processors.

OpenCL was released a little over two years after CUDA, in August 2009. So, it came late to the party, and had the lofty goal

of creating programs that would run on all devices, including standard CPUs, GPUs, DSPs, FPGAs, and more. Based around an implementation of C/C++, APIs for other languages—including Python, Java, and .Net—are available. This flexibility means OpenCL is even available for certain Android 7.1 devices, and developers are able to balance loads over available multiple GPU and CPU threads.

As you might imagine, the later appearance of OpenCL and more open design goals did impact its early performance against CUDA. A study at Delft University from 2011 showed that OpenCL suffered a 30 percent performance hit over CUDA implementations, although hand-tuning could mitigate the difference to a degree; other studies from the same period put the hit as high as 67 percent. However, things have progressed, and it appears that

more recent implementations running on AMD cards have managed to close down this performance gap—a 2017 report (www.blendernation.com/2017/04/12/blender-cycles-opencl-now-par-cuda) for Blender 2.79 showed OpenCL on a par with CUDA performance, although CUDA is still the fastest option for Nvidia hardware.

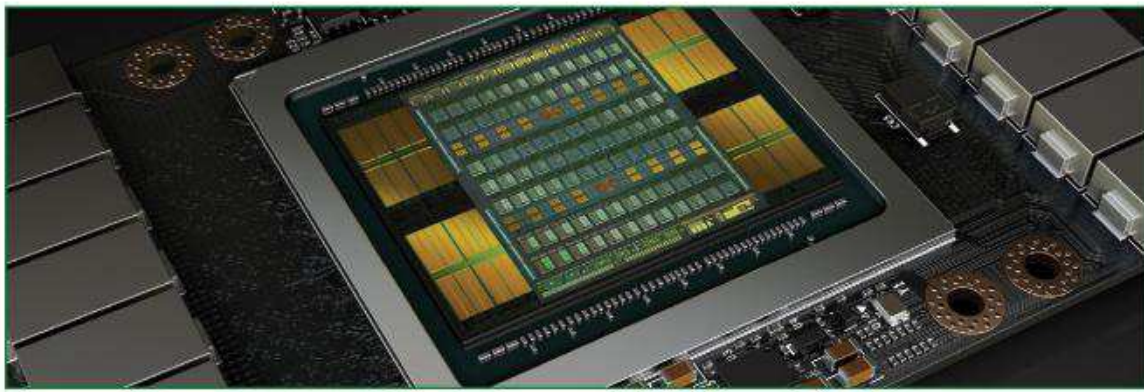
AROUND THE BLEND

At this point, you might be wondering what GPGPU has got to do with you—beyond the same hardware painting pretty 3D scenes on your monitor at 120fps, that is. It's certainly taken a good decade or so, but coders are now well aware of GPGPU capabilities, and the technologies to leverage them. You'll find a range of applications out there that can take full advantage of not just Nvidia cards with their CUDA technology, but also AMD and even potentially Intel GPUs (though often these are no faster than the CPU itself) utilizing OpenCL.

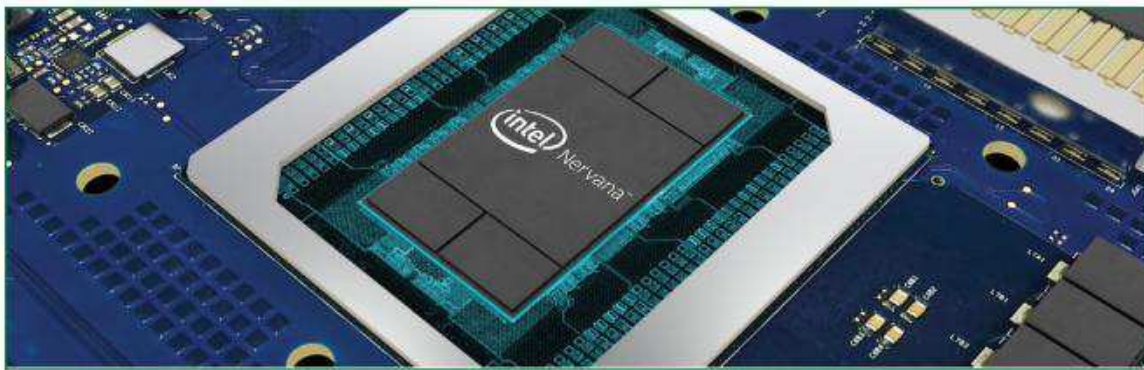
Because of the head start Nvidia built for itself, you do tend to find more CUDA software options available, but you'll discover that anything developed in the last five years should be offering the same capabilities for OpenCL, too. So, let's take a quick look at a few interesting software options you can play with now.

To kick off, we're going to suggest the hugely impressive open-source project Blender. It's a prime example of a key use for GPGPU in terms of ray tracing, while the open-source nature of Blender has meant there is now a burgeoning market in low-cost cloud render farms, which is one of the businesses driving Nvidia's data center division.

Blender is a monstrous package to master, but you can fire off a test render easily enough. A key strategy of the Blender Foundation is to provide all art resources



Nvidia's dedicated data center GPU, the Tesla V100, is capable of 125 teraflops.



Intel hopes to crack the deep-learning market in 2019, with its Nervana processor.

on an open license for everyone to enjoy—grab and install it from www.blender.org/download, then scroll down the page, and head to “Demo Files,” where you can also grab the famous BMW Benchmark file. If Blender is installed, you can just extract and run the appropriate CPU or GPU file—the main difference is the optimized tile size used. In Blender, press F12 to start a render. If you want to fiddle with the right-hand “Sampling” palette options, we’d reduce “Samples” from 35 to 15—this reduces quality for speed. Under “Performance,” you’re able to adjust tile size, too; 32–64 is ideal for CPUs, while 256 is better for GPUs.

For reference, we found our CPU was almost four times slower than the GPU here (CPU 4:39, GPU 1:22), but your results will inevitably vary.

FRACTAL FUN

The long-standing OpenCL program Mandelbulber (<http://mandelbulber.com>) is a 3D fractal explorer that supports OpenCL on AMD and Nvidia hardware. Download the latest 64-bit build from Sourceforge, and run it. Click the “Render” button to see how slow things are on your processor. Use “File → Program Preferences → OpenCL” to select a suitable platform (AMD or Nvidia) and your GPU device. On Nvidia hardware, you might initially see an error, as it defaults to AMD. Hit “Render” again and things should be far quicker—if the colors go an odd purple, change the OpenCL mode to “Medium” or “Full,” rather than “Fast,” over in the right-hand Navigation palette. We’re not going to try explaining any of this program—it’s just a bit of fun flying around abstract 3D fractals—but if you’re

interested, there’s a whole community around it at <http://fractalforums.org>.

As we’ve mentioned, GPGPU is fantastic at tackling repetitive math-intensive problems. One area that fits the bill perfectly is the field of encryption. Generally speaking, there’s no need for GPGPU acceleration for encryption, as that’s taken care of by CPU-based AES hardware acceleration, but one area that can take full advantage is hacking encrypted files.

The most well-known software in this area is the open-source program John the Ripper (www.openwall.com/john), but being contrarians, we’re going to look at the Windows (and Android) based Hash Suite (<http://hashsuite.openwall.net>), developed by a John the Ripper contributor. Both are designed to brute-force crack password-protected files—guessing a file’s password (the problem is that the permutations for any non-trivial-length password are vast). If you fire up Hash Suite and open its top-left menu, there’s a benchmark feature; the program automatically takes advantage of AMD or Nvidia hardware. You’ll see a general 20-fold increase in speed over using your processor, at least for our ancient Core i5-2500K versus GTX 950 system.

GPGPU tech is currently exploding, perhaps not so much in homes—where its main focus remains powering 3D graphics within PCs, phones, and consoles—but in data centers, high-performance computing, research labs, and beyond. That’s going to benefit all of us, as Nvidia, Intel, and AMD pour even more research effort into enhancing these already powerful processors, and developers get to leverage them with CUDA and OpenCL. ⚡



FOR SCIENCE!

 We’ve seen not only how standard GPGPU prowess can help accelerate standard applications, but also how GPGPUs are enabling high-performance computing solutions to build the next generation of multi-exaop speed supercomputers. The cores in those modern supercomputers are still, at heart, the same CUDA cores as in your Nvidia GPU, and the same capable OpenCL-powered stream processors that AMD uses. So the question is, can you turn your home GPGPU to science? Of course you can!

FOLDING@HOME

(<https://foldingathome.org>)

This is the biggest distributed computing project in the world, and back in 2016, it broke through the 100 petaflops level. Download the client and you can help researchers explore cures for Alzheimer’s, cancer, Parkinson’s disease, Huntington’s disease, and more.

SETI@HOME

(<http://boinc.berkeley.edu>)

We’d be surprised if you hadn’t heard of Seti@home, because it’s been searching for extraterrestrial life since 1999. Berkeley, which began SETI, has expanded its distributed computing system to a general open design called Berkeley Open Infrastructure for Network Computing, aka BOINC. This encompasses SETI@home and a whole lot more, and it also automatically takes advantage of any CUDA and OpenCL-capable resources.

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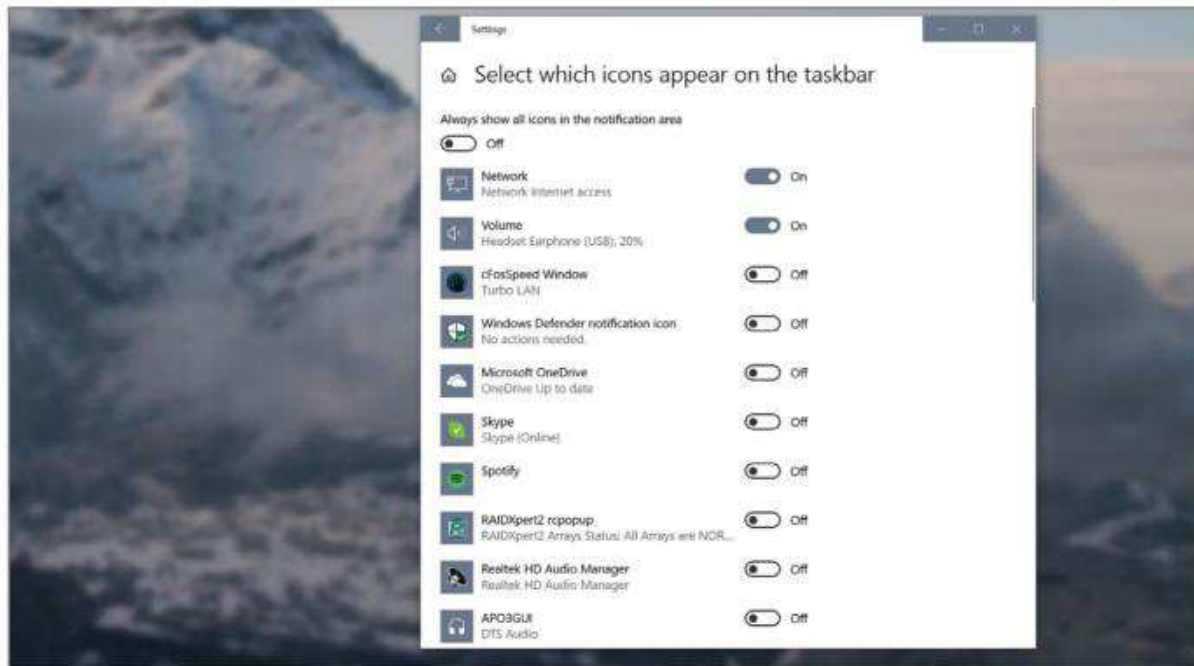
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STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



TASKBAR ICONS

Hidden at the bottom-right of the Start bar, taskbar icons show everything from network status to volume control, and other apps running in the background. By default, Win 10 only shows the volume status. To decide which icons aren't hidden in the drop-down menu, right-click the taskbar, select "Taskbar settings," click "Select which icons appear on the taskbar," then choose which ones you want even quicker access to.

MAKE – USE – CREATE



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Set up image recognition on your Raspberry Pi



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Add a dash of drama to your text with Photoshop



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Step-by-step guide to putting together a home theater PC



ZAK STOREY
DEPUTY EDITOR

HTPCs FOR EVERYONE

During the week, my after-work routine is simple. I get home, cook and food prep for the next day, jump on my main rig to relax with a game or two, pack my bag for work, then spend some time with the future Mrs Storey, watching a film or an episode of the latest series we're bingeing on, on our LG smart TV.

The thing is, I've been getting more and more frustrated with our TV. It never was particularly quick, but it's been getting slower and slower—it's driving me mad. Now, I'm not one to just sit and moan about my problems; I'm a doer. And the answer's straightforward, right? Three little words: home theater PC.

Admittedly, this is new territory for me. I've always been reluctant to dive into the world of media centers, as I assumed it was all going to be kernel-based Linux stuff (my kryptonite), but after seeing a few YouTube videos featuring Kodi setups running in Windows, I'm willing to give it a go.

As far as media is concerned, jumping over to your own HTPC makes the most sense as far as compatibility is concerned, but the big one for me is that everything's within my control. I dictate the hardware, I can maintain the rig, and I can choose exactly what I want on it. From a simple streaming box to a couch gaming rig, the outcome rests on what I do with it, and there's something appealing about that.

submit your How To project idea to: comments@maximumpc.com



AUTOPSY

THIS MONTH WE DISSECT...

Apple iPad 6



You'll reach the LCD panel quickly enough, but that's just the start of the journey.

About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.





Blasting the glue is an essential part of gaining access to the iPad's innards.



BACKGROUND

Unveiled at Apple's recent education-focused event, we expect the new iPad is less of a "hot new sequel" and more like a "revised edition paperback with improved illustrations." While this iPad's specs reveal two major updates—an upgraded processor, and Pencil support—has Apple quietly changed anything else? Let's find out with a teardown!

MAJOR TECH SPECS

- Apple A10 fusion processor with embedded M10 motion coprocessor
- 9.7-inch multi-touch Retina display with 2048×1536 resolution (264 ppi) and non-laminated display assembly
- 32GB or 128GB of storage
- 8-megapixel 1080p rear-facing iSight camera + 1.2-megapixel 720p front-facing FaceTime HD camera
- 802.11a/b/g/n/ac dual-band MIMO Wi-Fi + Bluetooth 4.2
- Touch ID fingerprint sensor + three-axis gyro + accelerometer + barometer + ambient light sensor
- Apple Pencil support

KEY FINDINGS

- We've been around this block a few times, so we're going to let ourselves in: iOpener brings the heat; suction and opening tool bring the prying leverage. Like magic, the digitizer panel lifts separately from the display—a good sign for repair. Non-fused display and digitizer glass are better in the event that either breaks. Important for a rambunctious classroom.
- After freeing some Phillips screws, we lift the LCD panel and disconnect it from the logic board. Before we go further, we slide a battery blocker between the battery and logic board to keep stray electrons from interfering with our teardown.
- Now we can safely disconnect the digitizer. It has the same two cables as before, but they look a little different. Could they have changed slightly for Pencil compatibility? Look what we found hiding under a shield: the same NXP 8461A1 Touch ID chip that we saw in the previous model.
- Strong adhesive binds the logic board to the case, so we meet it with some liquid fists. Pow! The offending adhesive quickly gives way, and the board comes out in one piece. And an unfortunate part of that piece is the Lightning connector, a high-use part that will very likely break before the rest of the logic board. You'll need some pretty serious microsoldering chops to pull off a simple port replacement here.
- We're pleased to see that Apple continues to use the battery from the iPad 5 here—model number A1484 with a 32.9Wh capacity. Not only does this make more of the same battery available, but reusing existing manufacturing lines usually means less waste. We're not as pleased that it also brought over the same repair-impeding adhesive from the iPad 5. The good news is that you can already get a replacement battery.
- Repairability score: 2 out of 10 (10 is the easiest to repair). The LCD is easy to remove once you separate the cover glass/digitizer. Air-gapped, separately replaceable cover glass and LCD makes many drop damage repairs far less expensive. As in all iPads, a solid barrier of very strong adhesive bars the way to any repairs, and makes rework a sticky proposition. More adhesive holds nearly everything else in place. Battery replacement is especially challenging. The LCD has foam sticky tape adhering it to the front panel, increasing risk of damage during disassembly. ⏻

Image Recognition on the Raspberry Pi

YOU'LL NEED THIS

RASPBERRY PI

The miniature computer costs as little as \$35.

WANT TO BUILD SOMETHING CLEVER using machine learning and some fairly serious tools? Good. We're going to use Google's TensorFlow to construct a neural network that can identify images seen by a PiCamera. You don't need to know anything about machine learning, and along the way you'll learn some key concepts, and start getting under the hood. We're using a PiCamera, but you can still do most of the tutorial even if you don't have one.

TensorFlow is Google's machine learning framework, used by engineers for research and to build production systems. It's a powerful tool, with an unlimited number of ways to explore it.

To use TensorFlow, you need to have a huge amount of data and a lot of computing power, neither of which we have. So, we're going to cheat by using an existing network that's been trained on lots of data, and chop off the last layer of the network, then train it on our own data.

This tutorial is based in part on TensorFlow for Poets (<https://tinyurl.com/tensorflowfp>), because it provides some good resources if you get stuck or want to take it forward. However, we'll build on top of this to give you an idea of what you can explore. —DAN FROST

```
→ tensorflow-for-poets-2 git:(master) * python3 -m scripts.retrain --bottleneck_dir=tf_files/bottlenecks/ --model_dir=tf_files/models/ --summaries_dir=tf_files/training_summaries/ --architecture=mobilenet_1.0_224 --output_labels=tf_files/retrained_labels.txt --image_dir=tf_files/flower_photos
INFO:tensorflow:Looking for images in 'salmon'
INFO:tensorflow:Looking for images in 'tuna'
2018-04-24 19:47:56.943134: I tensorflow/core/platform/cpu_feature_guard.cc:137] Your CPU s
binary was not compiled to use SSE4.1 SSE4.2 AVX AVX2 FMA
INFO:tensorflow:100 bottleneck files created.
INFO:tensorflow:Creating bottleneck at tf_files/bottlenecks/tuna/test.jpg_mobilenet_1.0_224
INFO:tensorflow:2018-04-24 19:47:59.783875: Step 0: Train accuracy = 72.0%
INFO:tensorflow:2018-04-24 19:47:59.785432: Step 0: Cross entropy = 0.718202
INFO:tensorflow:2018-04-24 19:48:00.933384: Step 0: Validation accuracy = 62.8% (N=100)
INFO:tensorflow:2018-04-24 19:48:00.953184: Step 10: Train accuracy = 98.0%
INFO:tensorflow:2018-04-24 19:48:00.953325: Step 10: Cross entropy = 0.035794
INFO:tensorflow:2018-04-24 19:48:00.9603625: Step 10: Validation accuracy = 95.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:01.198628: Step 20: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:01.198764: Step 20: Cross entropy = 0.007062
INFO:tensorflow:2018-04-24 19:48:01.161134: Step 20: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:01.654536: Step 30: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:01.654688: Step 30: Cross entropy = 0.003612
INFO:tensorflow:2018-04-24 19:48:01.703876: Step 30: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:02.201013: Step 40: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:02.201169: Step 40: Cross entropy = 0.003877
INFO:tensorflow:2018-04-24 19:48:02.252138: Step 40: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:02.768192: Step 50: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:02.768349: Step 50: Cross entropy = 0.001148
INFO:tensorflow:2018-04-24 19:48:02.817254: Step 50: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:03.330981: Step 60: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:03.331145: Step 60: Cross entropy = 0.001070
INFO:tensorflow:2018-04-24 19:48:03.387633: Step 60: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:03.977458: Step 70: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:03.977621: Step 70: Cross entropy = 0.002764
INFO:tensorflow:2018-04-24 19:48:04.026517: Step 70: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:04.561206: Step 80: Train accuracy = 100.0%
INFO:tensorflow:2018-04-24 19:48:04.561359: Step 80: Cross entropy = 0.001625
INFO:tensorflow:2018-04-24 19:48:04.611169: Step 80: Validation accuracy = 100.0% (N=100)
INFO:tensorflow:2018-04-24 19:48:05.159875: Step 90: Train accuracy = 100.0%
```

1 LET THE TENSOR FLOW

To install TensorFlow, we need to upgrade the framework and get the latest packages:

```
sudo apt-get update
```

```
sudo apt-get upgrade
```

```
sudo pip3 install --upgrade pip
```

» At the time of writing, TensorFlow isn't available as a Raspbian package, so we're going to install this using a pre-built binary. This will cause problems with version conflicts, so it's advisable to regularly check on Google for "install tensorflow raspberry pi."

» Let's grab and install the binary:

```
wget https://github.com/samjabrahams/tensorflow-on-raspberry-pi/releases/download/v1.1.0/tensorflow-1.1.0-cp34-cp34m-linux_armv7l.whl
```

```
sudo pip3 install tensorflow-1.1.0-cp34-cp34m-linux_armv7l.whl
```

```
sudo pip3 uninstall mock
```

» With that installed, let's run a simple script to check that TensorFlow is installed, and can be run:

```
import tensorflow as tf
hello = tf.constant("Hello, TensorFlow!")
sess = tf.Session()
print(sess.run(hello))
```

» Run it with `python3 test_tf.py` which, on our Pi 3 B, took a few seconds to run. With TensorFlow installed, let's get on with exploring some machine learning....

2 A POET'S LIFE

We're going to clone the popular TensorFlow for Poets repository, because this provides a great starting point, and enables you to dip your toe into some real machine learning code and data. First, clone the repo, move into the directory, and grab a tarball of image files with which we're going to retrain the network. This is achieved with the following:

```
git clone https://github.com/googlecode/labs/
tensorflow-for-poets-2.git
cd tensorflow-for-poets-2
curl http://download.tensorflow.org/example_images/
flower_photos.tgz | tar xz -C tf_files
```

» Next, we retrain using the command below, which downloads the mobilenet network. This is an existing machine learning model that has been trained on a lot of data. The command then removes the final layer of the network that labels the image, and retrains it using the files in "tf_files/flower_photos." Think of this as taking a network that can identify general shapes—such as edges, curves, and so on—and using that to describe the new training images, so that the resulting network can identify flowers:

```
python3 -m scripts.retrain \
--bottleneck_dir=tf_files/bottlenecks \
--how_many_training_steps=500 \
--model_dir=tf_files/models/ \
--summaries_dir=tf_files/training_summaries/
mobilenet_1.0_224 \
--output_graph=tf_files/retrained_graph.pb \
--output_labels=tf_files/retrained_labels.txt \
--architecture=mobilenet_1.0_224 \
--image_dir=tf_files/flower_photos
```

» This takes a few hours to run, during which time you'll see logs showing the network being downloaded, the bottlenecks being created, and it being retrained [Image A]. When this is done, you'll have some new files in "tf_files/":

```
$ ls -l tf_files/  
bottlenecks  
flower_photos  
models  
retrained_graph.pb  
retrained_labels.txt  
training_summaries
```

» The "retrained_graph.pb" is the new neural network that we can use to identify flowers, and which we can test using the label_image command:

```
python3 -m scripts.label_image --graph=tf_files/retrained_  
graph.pb --image=...
```

» The image flag needs to point to an image—one of the training images or a new one. For example, go to Google and search for a tulip [Image B], save it to the desktop as "new-flower.jpg," and run:

```
$ python3 -m scripts.label_image --graph=tf_files/retrained_  
graph.pb --image=/home/pi/Desktop/new-flower.jpg  
Evaluation time (1-image): 3.859s
```

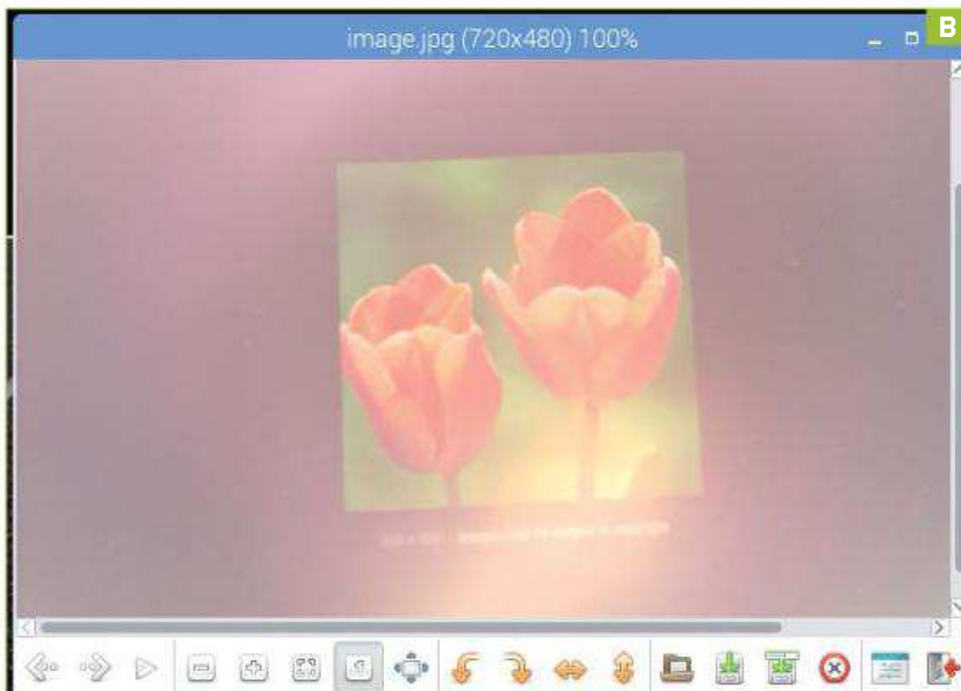
```
tulips 0.99234116  
roses 0.0066660508  
daisy 0.0008570712  
dandelion 7.7864344e-05  
sunflowers 5.789246e-05
```

» The label_image command is using the newly retrained network to identify how confident it is that new-flower.jpg is each of the categories we trained it with. Obviously, "dandelion" and "sunflowers" are very unlikely; "roses" and "daisy" are more likely, but still very low confidences; and "tulips" is nearly certain, with 0.99. That's quite a lot of magic you just did.

3 CAMERA ACTION

Let's build on that image recognition using a PiCamera. If you don't have one, you can just find images from the web, so do keep going.

» Plug in your PiCamera, then enable the camera by running `sudo raspi-config`, and navigating either to "camera" in the first menu, or to "interfaces," and then "camera." Enable the camera, then exit this config tool. Test it by running `raspistill -o ~/Desktop/image.jpg`, which captures an image to the desktop. Open it to confirm that everything is working.



HYPERPARAMETERS

As you dig deeper into machine learning, you'll find yourself tuning how the model is trained and retrained to improve its performance. You do this by altering things such as the number of layers in the network, and the number of training steps. These are called hyperparameters.

In machine learning, there are parameters and hyperparameters. Parameters are the data that the model turns into a prediction, such as pixels in the images, or words if we're doing text classification. Hyperparameters affect how well the model performs once trained.

For example, we're setting "how_many_training_steps" to 500, but it could be that 1,000 training steps would create a more accurate model, or maybe 300 is enough. Play about with the number. Retrain the network using fewer training steps, then see whether the confidence in identifying the image performs as well. Then retrain with more steps, and compare your findings.

If you get really into this, you can plot the performance of your model against the number of trained steps to find the optimum number. Doing this is known as "hyperparameter optimization."

» Let's make a simple camera script in cam.py:

```
from picamera import PiCamera as pc  
from time import sleep
```

```
cam = pc()  
image = "/home/pi/Desktop/snap.jpg"  
cam.capture(image)  
print("Captured in {}".format(image))
```

» Next, run it with `python3 cam.py` and check that snap.jpg contains a picture taken from the camera.

» It would be nice if the camera and identification steps all happened in one go. So, let's do it! We've pulled in parts of the TensorFlow for Poets script, so that you can start seeing how TensorFlow works [Image C], without having to dive into anything complex:

```
from picamera import PiCamera as pc  
from time import sleep, time  
import numpy as np  
import tensorflow as tf  
from scripts.label_image import load_graph, read_  
tensor_from_image_file, load_labels
```

```
cam = pc()  
image = "/home/pi/Desktop/snap.jpg"  
cam.capture(image)  
print("Captured in {}".format(image))
```

```
graph = load_graph('tf_files/retrained_graph.pb')
```

```
t = read_tensor_from_image_file(image,  
                                input_height=224,  
                                input_width=224,  
                                input_mean=128,  
                                input_std=128)
```

```
input_operation = graph.get_operation_by_  
name('import/input')  
output_operation = graph.get_operation_by_  
name('import/final_result')
```

TRAINING AND RETRAINING

A trained neural network is able to take in a piece of data, such as an image, that it hasn't seen before, and output a prediction about what the data is, such as a category of flower, fish, car, or whatever it's been trained on. The process of training takes heaps of training data, which in this case is images labeled by what's in them, and tunes all the nodes in the network to accurately categorize all that training data and new data.

This is done by turning the image into a huge number of parameters, which you can think of as each pixel or groups of pixels. Inside the network, there are weights and biases that determine which pixels and groups of pixels are used to identify which category the image is expected to be in.

Training a network requires lots of data and computing power, which you don't have on a Raspberry Pi. Yet it turns out that you can retrain a network by taking an existing trained network, which uses much less power and data.

Retraining enables you to take an existing network, keeping most of the network, but replacing the final categorization layer to suit your new training data (the labeled images). You can think of this as keeping the parts of the network that can identify shapes, while replacing the final layer, which categorizes images, and using that ability to identify shapes.

```
with tf.Session(graph=graph) as sess:
    start = time()
    results = sess.run(output_operation.outputs[0],
                       {input_operation.outputs[0]: t})
    end = time()
```

```
results = np.squeeze(results)
```

```
top_k = results.argsort()[-5:][:1]
```

```
labels = load_labels('tf_files/retrained_labels.txt')
```

```
for i in top_k:
```

```
    print(labels[i], results[i])
```

» Run this script to take a picture, and identify it with `python3 cam2.py`. Nice work! But let's do more....

4 RETRAINING

So far, we've just used the supplied image files. That's pretty boring, but data is what makes machine learning work and if you don't know how to get more data, you'll just be stuck on the same old examples. So, time to get some more data.

» To do this, you need to grab hundreds of images of a few things, which doesn't sound like fun. So, let's cheat. Install the Chrome extension Fatkun Batch Download Image (<https://tinyurl.com/fatkun>), go to Google Image Search, and grab several hundred images of a few things.

» For example, you could download 700 or so images of different types of fish [Image D], or specific people, types of food, or makes of car. Search for each category of image, click the Fatkun icon in the top-right, and download all the relevant images (you'll have to ignore some social media images that appear in the image search).

» Save the images into a new directory called "tf_files/retraining," with each directory being the label you want to use. For example:

```
./tf_files/retraining/trout
./tf_files/retraining/salmon
./tf_files/retraining/crab
./tf_files/retraining/...
```

» When you've done this, delete the files associated with the previous retraining, and then run the retraining script, as follows:

TensorFlow™ Install Develop API (1.7) Deploy Extend Community Versions TFRC Search

An open source machine learning framework for everyone

[GET STARTED](#)

TensorFlow 1.7 has arrived!

We're excited to announce the release of TensorFlow 1.7! Check out the announcement to upgrade your code with ease.

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TensorFlow Dev Summit 2018

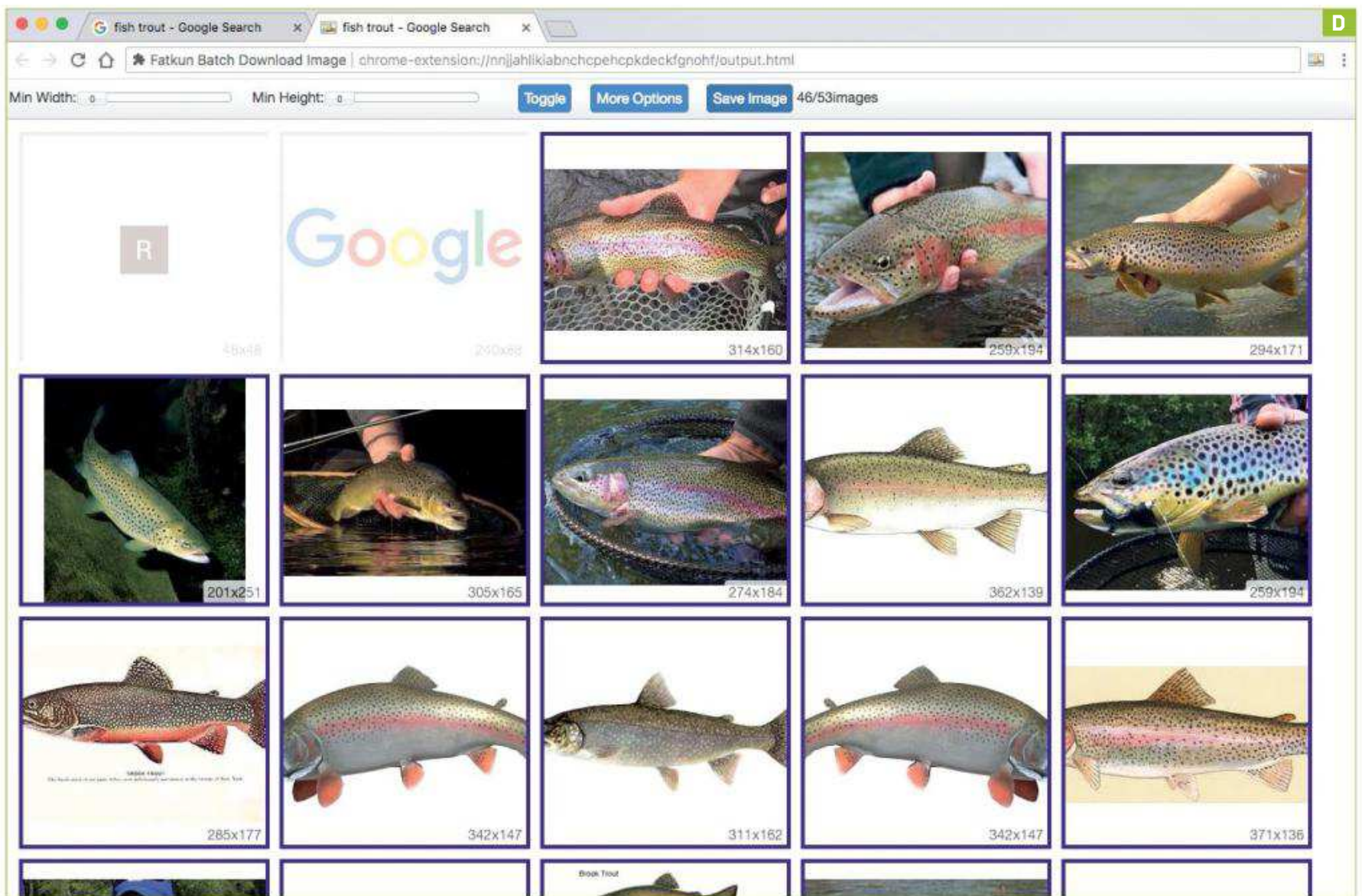
Thousands of people from the TensorFlow community participated in the second TensorFlow Dev Summit. Watch the keynote and talks now.

[WATCH NOW](#)

Announcing TensorFlow.js!

Learn more about our new library for machine learning in the browser using JavaScript.

[LEARN MORE](#)



```
rm -fr tf_files/bottlenecks tf_files/flower_photos tf_files/
models tf_files/retrained_graph.pb tf_files/retrained_labels.
txt
```

```
tf_files/training_summaries
```

» You don't actually have to delete all of those, but it makes more sense to start from a clean slate. Now retrain with the following:

```
python3 -m scripts.retrain \
--bottleneck_dir=tf_files/bottlenecks \
--how_many_training_steps=500 \
--model_dir=tf_files/models/ \
--summaries_dir=tf_files/training_summaries/
mobilenet_1.0_224 \
--output_graph=tf_files/retrained_graph.pb \
--output_labels=tf_files/retrained_labels.txt \
--architecture=mobilenet_1.0_224 \
--image_dir=tf_files/retraining
```

» Now you can run your camera identification script to spot fish:

```
pi@raspberrypi:~/tensorflow-for-poets-2 $ python3 cam2.py
Captured in /home/pi/Desktop/snap.jpg
trout 0.8864375
salmon 0.086706705
crab 0.013091834
```

S MORE TRAINING

In this tutorial, you've installed TensorFlow, and retrained an existing neural network, which has introduced some of the key concepts in using machine learning. You then used the camera, which means you can start identifying objects in the real world. So, where to go from here?

» Well, you could build something that identifies faces of people as they walk down a corridor, or something that identifies items in a box. Because the Raspberry Pi doesn't need access to the Internet,

your setup could be used to identify objects where there's limited connectivity.

» If you're keen to learn more about TensorFlow, explore the scripts in TensorFlow for Poets, but also look at how you can reuse the scripts we put together here. There are many TensorFlow tutorials and models available to help you get deep into machine learning. Learn and enjoy!

6 WHAT NEXT?

When you've got your head around TensorFlow and created a few successful models, you'll want to build something useful. You could identify specific vehicles to gather traffic data, or to make decisions, such as telling you that your online shopping order has arrived.

» You could download all your Facebook data and tag up the images of people's faces, so you can identify people walking up to your door. Or, if you're a bird watcher, you could keep track of the local avian population—you'd need to tackle identifying the images in a video and creating your own training set.

» To see what sort of thing is possible, read www.svds.com/tensorflow-image-recognition-raspberry-pi, where they were able to detect the direction and speed of trains using the methods you've explored in this article.

» A couple of sites worth exploring are www.kaggle.com and www.kdnuggets.com. Kaggle hosts data science competitions, which means there's data and examples to follow. KDnuggets has posts on machine learning and data science, from the basics up and the math. Also take a look at <http://distill.pub>, which is geared toward making ML research accessible, and has some great, often in-depth articles on the research side of machine learning. ⚡

Edit Your Movies With the Photos App

YOU'LL NEED THIS

WINDOWS 10

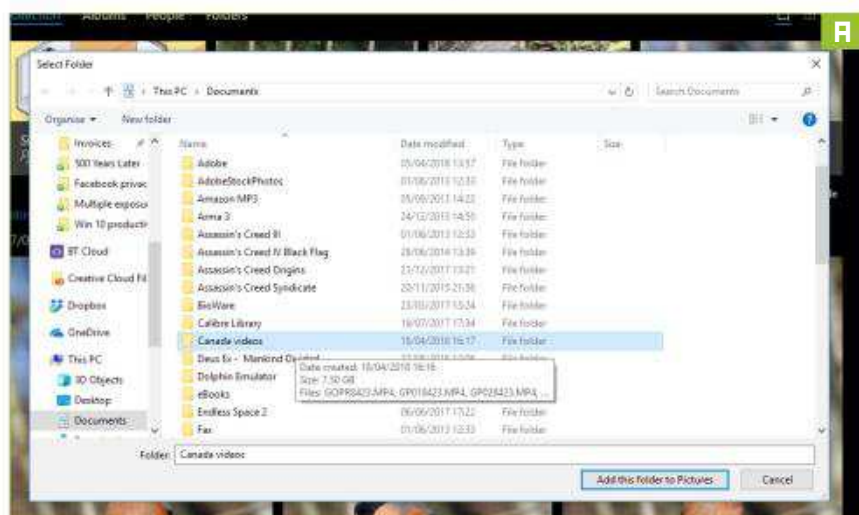
With the Fall Creators Update.

WINDOWS 10'S PHOTOS APP got a lot of love from last year's Fall Creators Update. Among many other improvements, it gained the ability to edit videos, something you wouldn't expect from an app simply called "Photos."

In the absence of a standalone Videos app—and with the old Windows Movie Maker now removed from Microsoft's website—Photos is the best free video-editing app you can get, without delving into either the uncertainties of the Microsoft Store or the wilds of the web.

In Photos, you can arrange and trim your home movies, add music, titles, and effects, and export the whole project as a file that's ready to be uploaded to YouTube or for playing on the family TV.

Photos' video-editing capabilities aren't complex, but they are simple to master, and can create a really good-looking video from your clips. **—IAN EVENDEN**

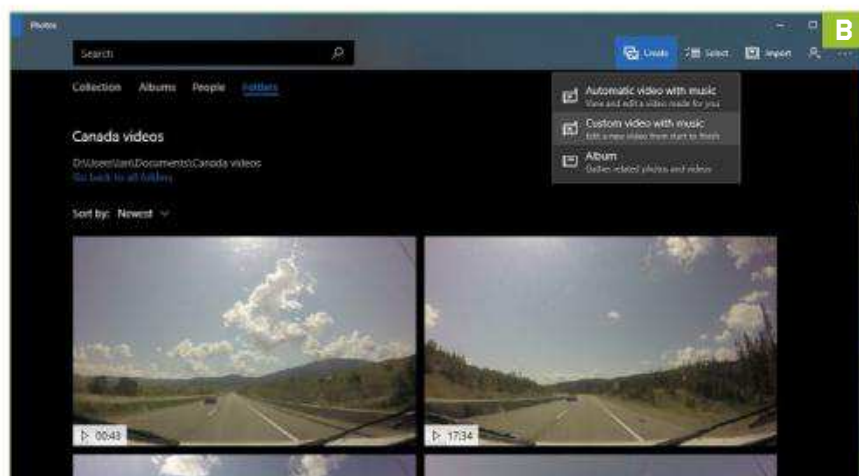


1 IMPORT YOUR FILES

There's an "Import" button at the top-right of Photos' interface, which drops down to give you the option of importing from a folder already on your PC, or from a connected USB device. The button that appears if you choose a folder isn't "Open" or "Import," but "Add this folder to Pictures" [Image A]—you're linking the folder to Photos, so it knows it's somewhere your files might be.

2 CREATE A PROJECT

Open "Folders," and select a folder containing video clips you want to use. Then, from the "Create" menu, choose "Custom video with music" [Image B]. The app automatically assembles a video for you if you choose that option, but you're better off doing it manually, because Photos' algorithms don't know what's important to you in a video clip. Give your creation a name, which you can edit later.



3 ARRANGE AND TRIM CLIPS

Photos normally puts your clips in chronological order, using their time and date stamps, but you can also drag and drop clips into the order you want using the storyboard along the bottom of the window. When your clips are in the correct order, trim any unwanted bits at the beginning and end using the "Trim" button; click it, and your selected clip appears, with blue markers you can move [Image C].

4 ADD A TITLE

Titles are easy to create. Select the first clip in your storyboard, and click the "Text" button above it. This switches to a dedicated window, from where you can choose a position and a text style to accompany your





chosen video title [Image D]. Use the “Filter” button to adjust the color balance of your clip. There aren’t many title styles, but they can be applied with a single click.

5 ADD MOTION

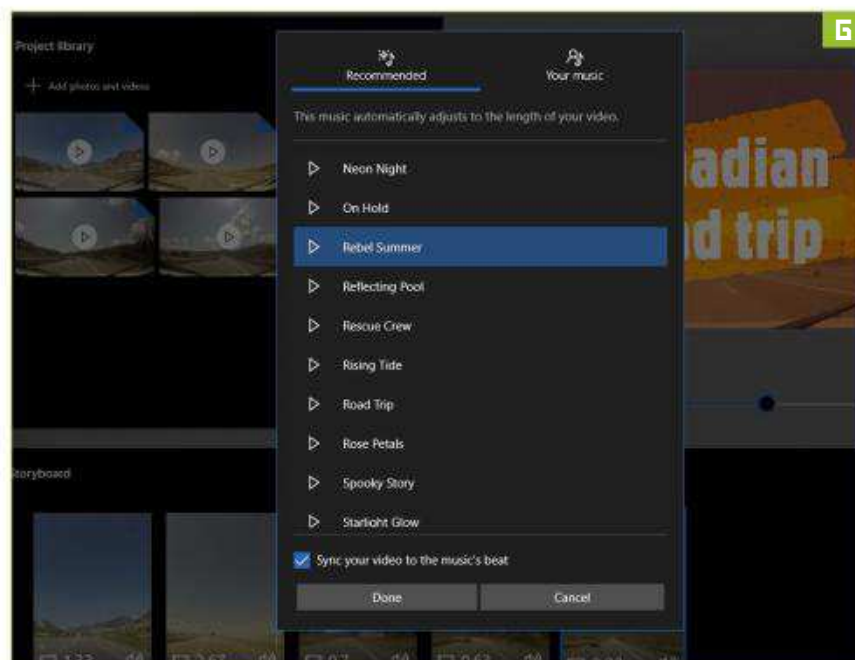
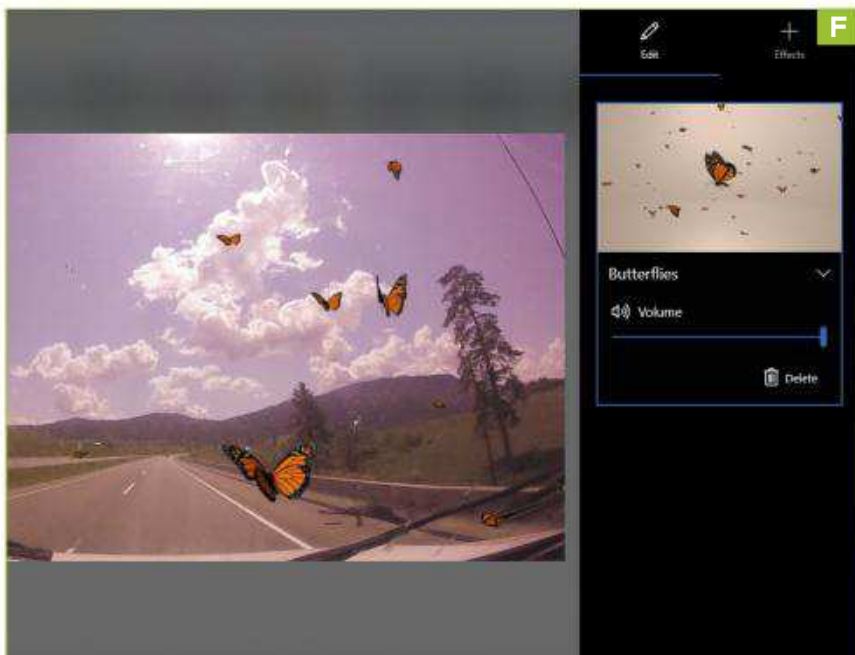
The next button along is “Motion” [Image E], which enables you to zoom into your clip and pan the viewpoint as if it were a virtual camera. The effect takes place across the entire length of the clip—there seems to be no way to affect its duration—and it can be relatively subtle, but the sense of movement it imparts is undeniable. There are 11 tilts, zooms, and pans to choose from.

6 ADD A THEME

The “Themes” button is at the top of the interface, next to the handy “Undo” and “Redo” buttons. Selecting a theme changes every filter, music clip, and text style you’ve used in your video to one set by theme, giving your movie a consistent look and feel. You can change themes, just by selecting them from the list on the right of the window that pops up when you press the button.

7 ADD 3D EFFECTS

These are a selection of special effects that insert various items into your video, from snowflakes to butterflies [Image F], and are accessed using the 3D button above the storyboard. You can choose how much of a clip an effect is visible on by dragging the blue bar across its running time. Effects with sound can have their volume modified. 3D effects can also be customized.



8 ADD MUSIC

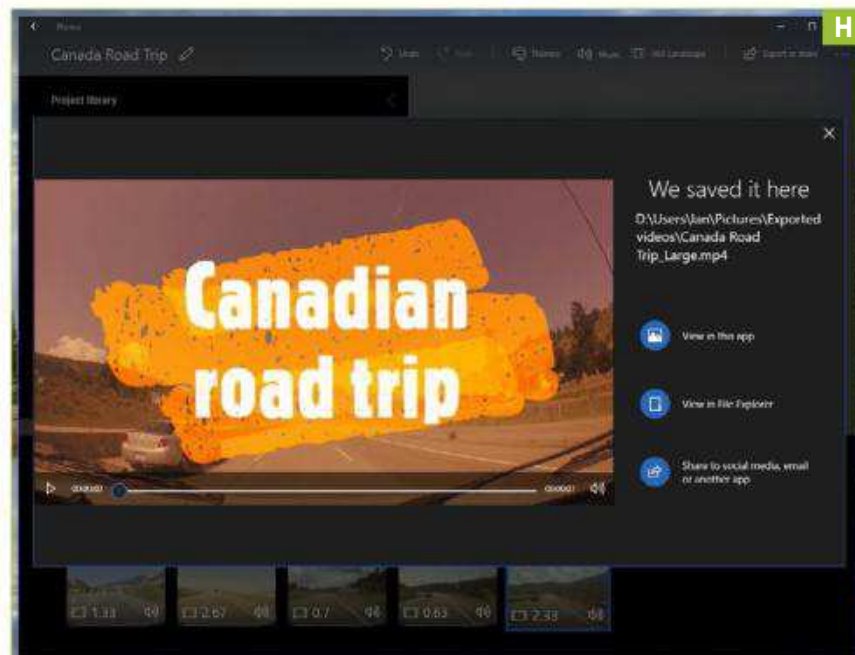
Photos comes with built-in music clips to accompany your video. Find them by clicking the “Music” button at the top of the main window (click the word “music,” not the speaker), then the “Recommended” tab [Image G]. These tunes can be synched so their beat affects movie playback, but there’s no way to control how this is done. Click the arrow next to each one to hear a preview.

9 GET MORE MUSIC

Select the “Your music” tab and you can use music files on your PC. Photos finds and flags up every music file on your PC, but some of these will be protected by copyright. Because YouTube takes a dim view of copyright infringement, and mutes videos in which it detects copyrighted music, get some Creative Commons-licensed tunes from www.bensound.com instead.

10 EXPORT AND SHARE

Photos offers three options for exporting your video: “Small,” “Medium,” or “Large.” If you’ve shot in HD, you might be disappointed by Small or Medium, which resize your video to 940x540 and 1,280x720 pixels respectively. Large keeps the full 1,920x1,080 resolution, but takes longer to produce with larger file sizes. Your movie is saved to your PC, and can be shared on social media [Image H].



Increase Your Facebook Security

YOU'LL NEED THIS

FACEBOOK ACCOUNT

And the desire to restrict what you share with the world.

THERE'S A LOT OF CONCERN about online privacy nowadays, particularly on Facebook in the light of the Cambridge Analytica scandal, in which personally identifiable data on over 87 million Facebook users was collected without their consent—if it's not your friends guessing your password and posting hilarious jokes under your name, it's the more sinister abuse of your personal information.

There are steps you can take against these intrusions, both on Facebook and on the wider web. The latter boils down to making sure your passwords can't be guessed, worked out through social engineering, or put together from multiple sources. They need to be long, too, so a brute force attack—which tries multiple passwords extremely quickly—takes much longer to work through the permutations. No using your date of birth or the name of your cat, either, unless you know the secret name Mr. Tickles only tells other cats. **—IAN EVENDEN**

1 DISABLE PLATFORM

The nuclear option. Turning off Platform prevents the integration of Facebook with apps and games, disables the ability to log into websites using your Facebook ID, and stops friends' Facebook apps accessing your personal information. Turning Platform off might be inconvenient, but its security benefits are undeniable. Find it in "Settings," under "Apps and Websites" [[Image A](#)].

2 INCREASE PRIVACY

Facebook is finally clamping down on access to your data, but there's more you can do to hide things. Under "Settings → Privacy" [[Image B](#)], you can change who sees your posts, with several levels of control. "Public" posts are just that—public. Anyone can see them. "Friends" means only Facebook friends can see your posts, and you can control this further by excluding people.

3 LIMIT ACCESS

Still in "Settings → Privacy," if you want to stop specific people seeing your posts, you can [[Image C](#)]; you can also specify friends who can see your posts while excluding everyone else. There's also "Only Me," which restricts the visibility of your posts to just you. It makes Facebook awfully quiet, but is the most private you can get. There's an array of custom settings, too.

4 PRIVACY CHECK-UP

One way to check your privacy settings is to use the Privacy Check-up feature, which can be found by dropping down the question mark menu at the top-right of Facebook's interface. This takes you through common settings, including whether those people who can see when your birthday is can also see the year you were born. There's also a shortcut to the privacy settings.

5 CREATE A STRONG PASSWORD

The key to a strong password is creating something you will remember but no one else can guess. Long strings of random characters are tricky to commit to memory, but a password made up of three words is much easier to recall: "Horse Duck Gibbon," for example. Extra capital letters and a number on the end decrease the chance of cracking it. The longer you can make it, the better [[Image D](#)].

6 USE TWO-FACTOR AUTHENTICATION

Two-factor authentication involves a message being sent to your cell phone after you have entered your username and

password, with a code that you then type into the website to verify that it's actually you. It means trusting the site in question with your phone number, but if someone guesses your password, they're unlikely to have stolen your cell phone, too, and this method tips you off about any login attempts [[Image E](#)].

7 USE A PASSWORD MANAGER

Password management apps—such as 1Password, Keeper, and True Key—sit between you and the website you're logging in to. They generate and store your passwords—strong, long, random sequences that you might struggle to recall, but apps have no problem remembering. When you log in to the management app, it supplies the password directly to the site. They usually require a monthly subscription, though.

8 DELETE APPS YOU DON'T USE

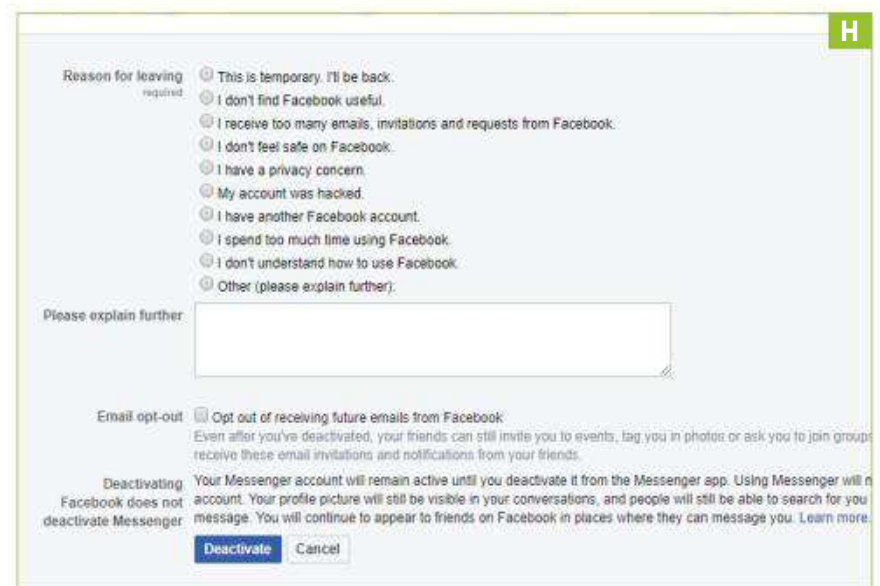
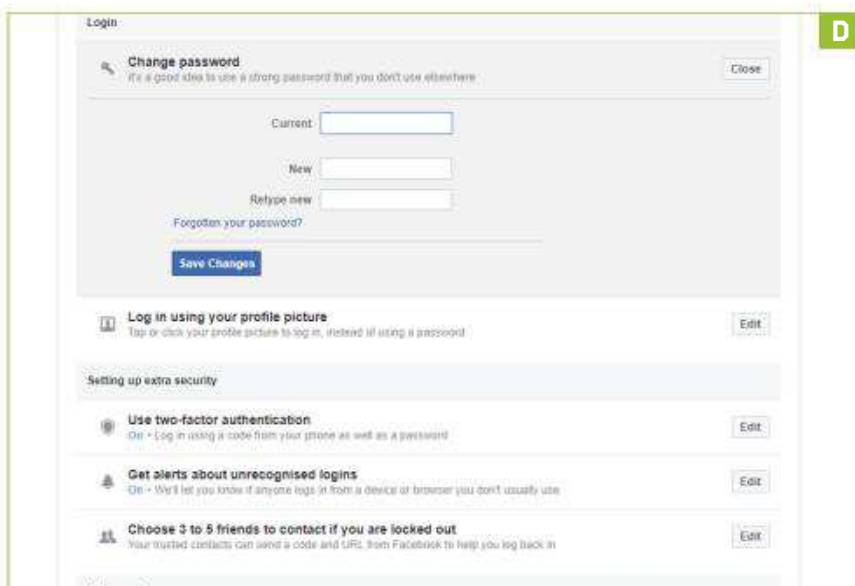
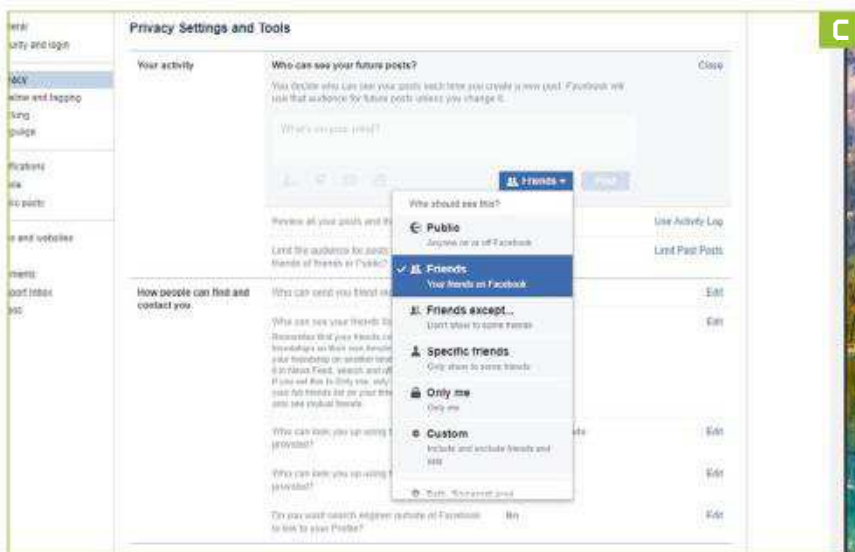
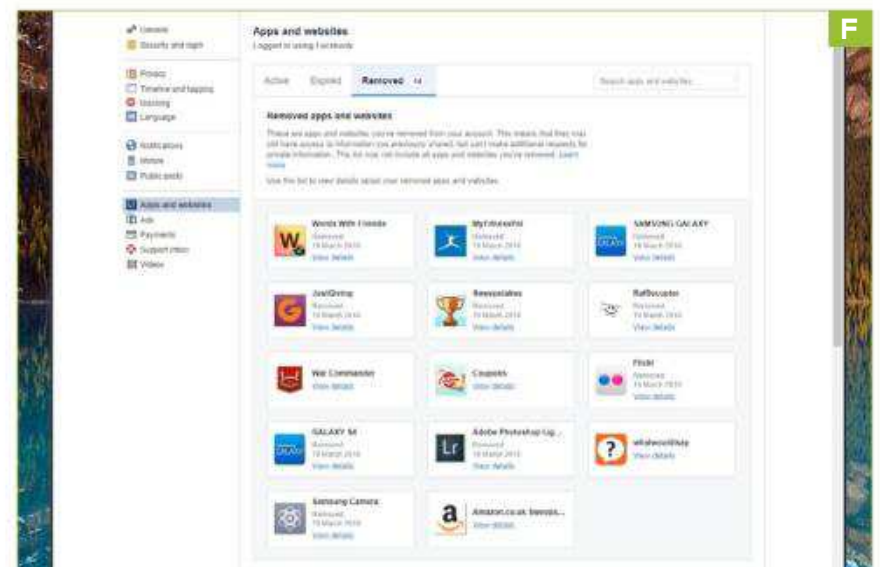
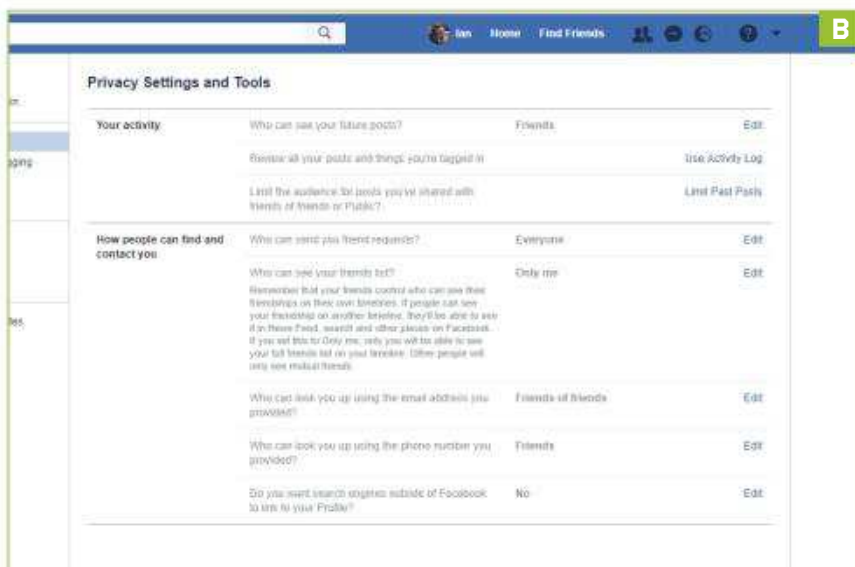
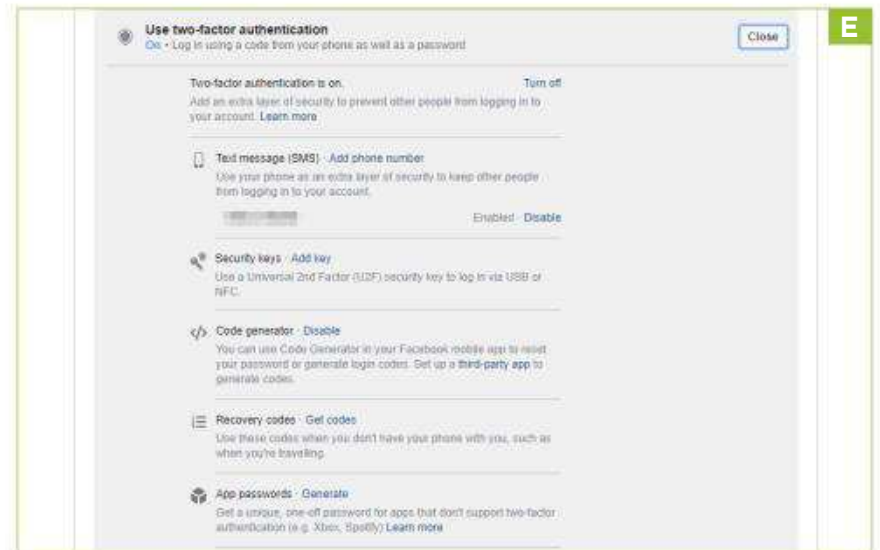
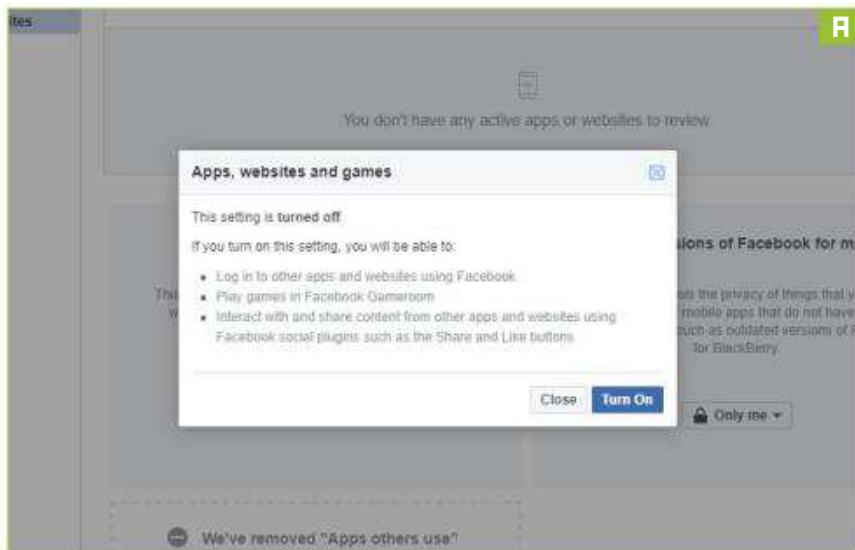
Under "Settings → Apps and Websites," you'll find a list of apps and sites you've approved for access to your Facebook account. If you no longer use—or don't recognize—any of them, you can revoke their access or edit the kind of data they have access to [[Image F](#)]. Also check the "Expired" tab for apps you may not have used recently, and which can no longer make requests for data.

9 LOG OUT WHEN FINISHED

It may sound simple, but this is one of the best security measures you can take, especially if you share your PC with others. Logging out [[Image G](#)] puts an obstacle in the way of those who would use your social media accounts for evil, particularly the jokers who send messages in your name. Of course, if you've set your browser to remember your password, then logging out is no defense at all.

10 DEACTIVATE YOUR ACCOUNT

Note: Deactivation is not the same as deleting—if you ever log back in to Facebook, perhaps when redirected from another site, your account will reactivate, and pop back up again, just as it was when you deactivated it. To do it, head to "Settings → General." Click "Edit" next to "Manage Account," then "Deactivate your account" [[Image H](#)]. One more click, and you're free.



Play Classic Games With DOSBox

YOU'LL NEED THIS

DOSBOX

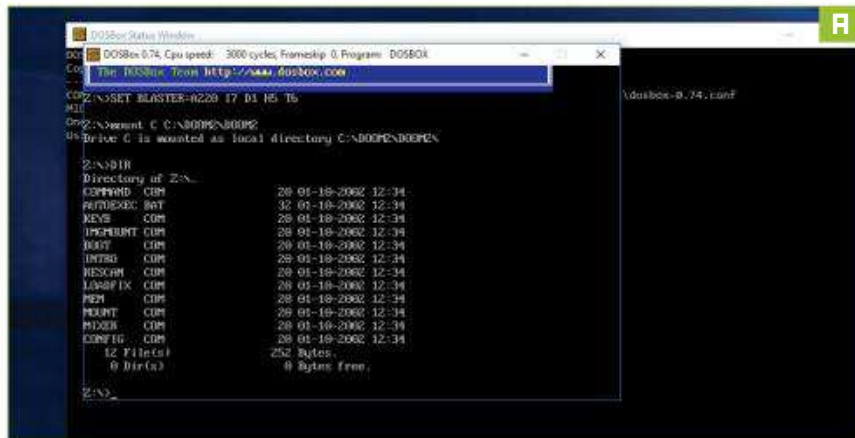
Download the software for free from www.dosbox.com.

VINTAGE GAMES

You need either the original game files or a CD.

IF YOU LIVED THROUGH THE '90S, you probably have fond memories of gaming classics such as *Red Alert*, *Doom*, and *Starcraft*. Despite the clunky graphics and witless AI, it's hard to recapture the sense of excitement that came from giving Stalin a bad day, or battling against the forces of hell on the moons of Mars. Sadly, most of these vintage gaming classics don't work natively on modern PCs. This dilemma is the focus of the DOSBox project, an emulator designed to mimic Intel x86. The emulator's primary focus is to play games that were released prior to Windows XP (2001), but in practice, you can actually run a number of DOS/Windows programs. The DOSBox website maintains a database of all supported software (www.dosbox.com/comp_list.php?letter=a).

You'll notice that DOSBox bears an uncanny resemblance to MS-DOS itself. This is all part of the fun: You only need to master a few commands to relive your gaming glory days. In this guide, you'll discover how to get started, as well as how to access more advanced options. We also cover how to connect a gamepad or joystick, as well as how to configure DOSBox for LAN gaming. —NATE DRAKE



1 INSTALL AND LAUNCH DOSBOX

To get started with DOSBox, open your web browser, and navigate to www.dosbox.com. Select the "Downloads" tab, then click the green "Download Now" button. Once the download is complete, open your downloads folder, and double-click to launch the DOSBox installer. Click "Yes" to allow Windows 10 to begin installation. Click "Next" to continue, then do the same when DOSBox asks you to choose which components to install.

Click the "Install" button to finalize installation. A shortcut to DOSBox now appears on your desktop.

2 PREPARE GAME FILES

For security reasons, DOSBox can't access your disk drives directly. Instead, it mounts folders as virtual drives. If you have multiple games, consider creating the folder "C:\GAMES" or similar, so you can access all your titles from one place. For the purposes of this guide, we've used a shareware version of the first-person shooter *Doom 2* (available from www.dosgamesarchive.com/download/doom).

» If you are lucky enough to still own the original CD of a particular game, such as *Tomb Raider II*, but don't have regular access to an optical drive, you need to create an ISO image, so DOSBox can access it. Utilities such as Alcohol 120 can do this for you. See <http://support.alcohol-soft.com/knowledgebase.php?postid=27806> for more information.

» Copyright law in some countries permits software owners to copy disks to a new medium for their own use—for example, by creating an ISO, as outlined above. Some states also permit downloading games from what are known as "abandonware"

websites, because the copyright holder no longer exists. Take some time to research what's legal in your jurisdiction before proceeding.

3 MOUNT AND RUN YOUR FIRST DOSBOX

Double-click the DOSBox icon on your desktop to launch the emulator. If you've previously used MS-DOS, the interface should look reasonably familiar [Image A], but bear in mind that DOSBox only recognizes a few MS-DOS commands.

» Begin by mounting your game folder as the C virtual drive—for example:

```
mount C C:\GAMES\DOOM2
```

» If your game is stored on an ISO, mount it as virtual drive "D" with `imgmount` so the command becomes:

```
imgmount D C:\GAMES\STARCRRAFT.iso -t iso
```

» Once your virtual drive is mounted, switch to it by running the command:

```
C:
```

» For ISOs run:

```
D:
```

» You next need to run either the game executable or the corresponding setup program to install the game files. Use the following command to list all the files and folders in the current directory:

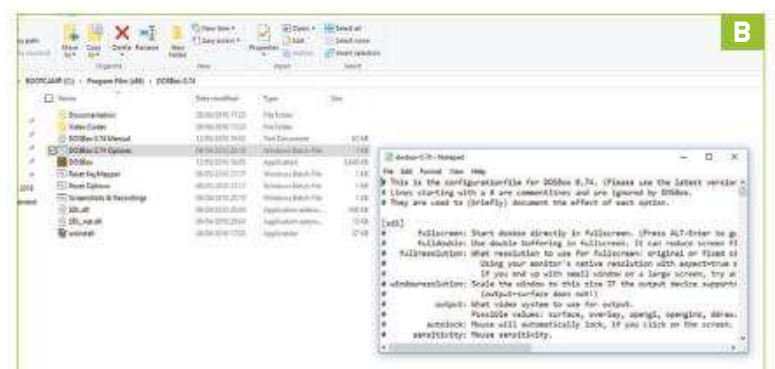
```
DIR
```

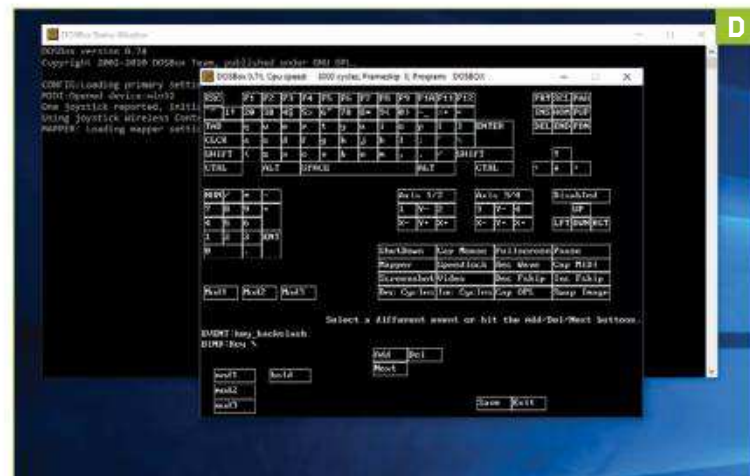
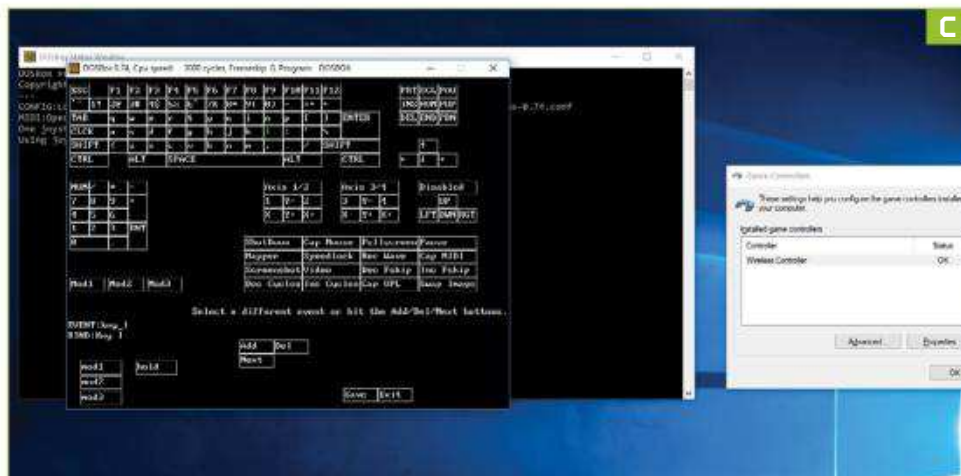
» You can use this command to switch to a new directory:

```
CD <FOLDERNAME>
```

» Once you've located the correct file, run it by typing the full name—for example:

```
DOOM2.exe
```





4 ACCESS DOSBOX CONFIGURATION SETTINGS

All DOSBox emulation settings are managed via the “DOSBox.conf” text file [Image B]. In Windows 10, you can find this file within your “AppData” folder—for example, C:\Users\Nate\AppData. DOSBox should also display the location of your configuration file inside the main window when you launch the emulator. If the file doesn’t yet exist, you need to open DOSBox, and run the following command to create a configuration file in your directory:

```
config -writeconf dosbox.conf
```

» Open the file “C:\Program Files (x86)\DOSBox-0.74 Options.bat” to view the DOSBox configurations in Microsoft Notepad. Each separate option is listed on its own line. Those lines that begin with “#” are ignored by DOSBox. However, you can read these lines to explore what each option does and view any alternative settings. For instance, `output` can be set to `opengl`, which offers faster performance, but potentially more blurry graphics. You can also toggle simpler options, such as setting `fullscreen=true`, for example.

» You’ll get the very best from your emulation experience by customizing your configuration for each game you play through DOSBox—it supports multiple configuration files. To launch the emulator with a specific one, use the command-line argument `-conf w`. The simplest way to do this is by modifying the DOSBox desktop shortcut.

5 GAMEPAD CONFIGURATION

DOSBox supports many game controllers and joysticks out of the box. In the configuration file, `joysticktype` is set to `auto` by default, enabling automatic detection of devices. If you have a specific type of controller, you can specify this here as well. Visit the DOSBox manual for a full rundown of these options (www.dosbox.com/DOSBoxManual.html#Joystick).

» Before you can use your gamepad with DOSBox, you must also ensure it can be detected by Windows. First, connect the controller to your USB port. In Windows 10, a notification should appear automatically to say that the device is connected. For this tutorial, we used a PS4 wireless controller connected by USB cable.

» To check your gamepad is working, click the Windows 10 “Start” menu, and enter “game” in the search bar. Next, click “Set up USB game controllers.” This opens the control panel, and your gamepad appears. Click “Properties,” then open the “Settings” tab to access the calibration options.

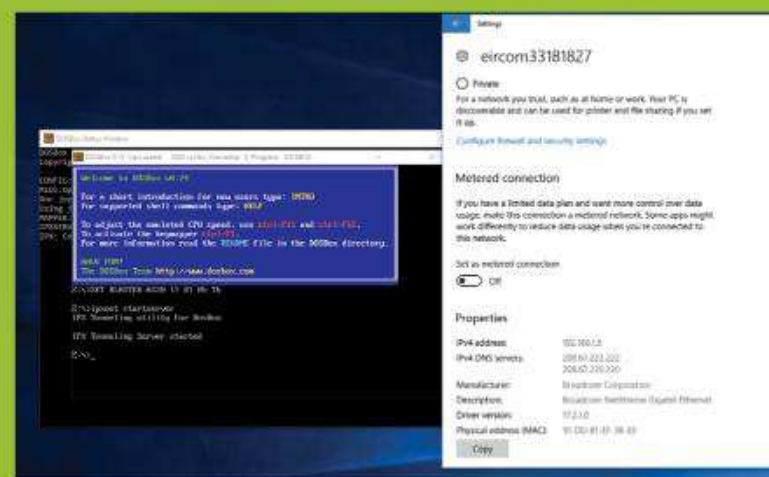
» Only certain DOS games are configured to work with joysticks and gamepads. For instance, *Doom* works with the keyboard by default. If you want to use a modern controller with a classic DOS game, press Ctrl-F1 when running DOSBox. This opens the “mapper” [Image C]. From here, you can bind gamepad buttons to keys. For instance, to bind the S key on your keyboard to the “Down” button on your controller’s Dpad, use your mouse to click on the key in the mapper window, select “Add,” then hold “Down” on

the Dpad. Repeat this process for each of the keys used in game. Click “Save” when done to store your settings.

6 ADVANCED TWEAKS

One of the most common complaints of DOSBox users is that they can’t find the all-important backslash (\) on their keyboard, which is necessary for accessing files and folders. The easiest workaround is to use the mapper, as outlined in the previous step, to reassign backslash to another keyboard key [Image D].

» Certain DOS programs may require more memory than the amount DOSBox allocates by default (16MB). You can alter this by accessing the configuration options as outlined in Step 4, then changing `memsize=16` to something more suitable. ⚡



DOSBOX MULTIPLAYER

DOSBox is capable of emulating the IPX (Internet Package Exchange Protocol), which was used for playing network games in classics such as *Doom* and *Quake*. In simplest terms, one computer acts as the games server to which other players can then connect. To get started, open the file “C:\Program Files (x86)\DOSBox-0.74 Options.bat” to access the DOSBox configuration. Scroll down to `ipx=false` and change it to `true` to enable IPX.

Next, open DOSBox on the machine you want to use as a server, and run the command `ipxnet startserver`. Ask each of the players on your local network to launch DOSBox and run the command `ipxnet connect <ip>`, where “ip” is the local IP address of the server. In Windows 10, you can find this by opening the Start menu, and searching for “Ethernet.” Select your network name from the menu. A window opens displaying your IPv4 address under “Properties.” You should now be able to host a match using the in-game options.

Add a Dash of Drama to Your Text

YOU'LL NEED THIS

PHOTOSHOP

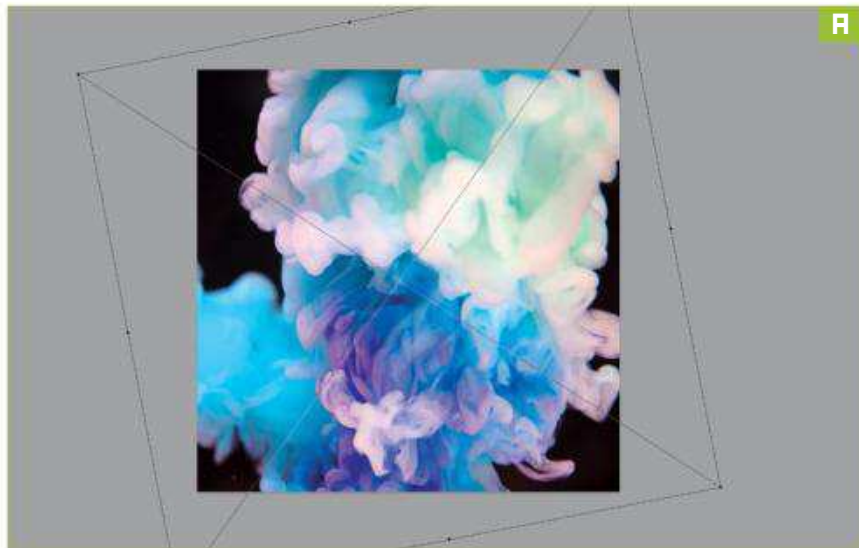
You can subscribe to various packages at www.adobe.com. Alternatively, use Photoshop Elements or GIMP.

TEXT IS FINE. IT'S OK. There's plenty of it in this magazine—but, with apologies to the vast design and sub-editing departments, it's not very exciting.

It doesn't have to be this way, however. With a bit of Photoshop know-how (there's nothing too CC-specific here; it could be done in Photoshop Elements or GIMP, for that matter), you can whip up exciting-looking text snippets that, if kept simple enough, could be used for a logo or as an eye-catching header for a newsletter.

The trick we're using is a Layer Mask, which enables you to affect how transparent a layer is by painting directly on the layer. Much of the time, this changes between 0 and 100 percent opaque, but with a soft-edged brush, you can have semi-transparent areas that look natural.

The Layer Mask isn't just used to make type more interesting; it's an essential Photoshop skill used for creating all sorts of effects. Master this, and a whole world of advanced techniques opens up. So, let's mask! **—IAN EVENDEN**



1 FIND YOUR PICTURE

Finding an appropriate source picture may mean trawling through public domain photo sites—or an instructive afternoon with a DSLR and matches in a well-ventilated garage—but what we're looking for is some colored smoke, or an explosion of dry powder, or even something like the Crab Nebula, a supernova remnant left over from a massive star that exploded in 1054. Whatever you choose, it needs curlicues, offshoots, filaments, or even tendrils for you to wind in front of your text.

2 SPIN CYCLE

It's worth considering whether your text is going to run perfectly horizontally or not. If it is, you can rotate your image (double-click the background layer to make it a floating one, then use "Free Transform" from the "Edit" menu), so that part of it also runs horizontally [Image A]. This will make things easier later.

3 ADD YOUR TEXT

Once you've chosen your image and got it ready in Photoshop, the next step is to write your text. It's best to keep it short, as not only does this allow you to make the type larger, but it makes it easier for readers to recognize the word, even if it's partially obscured. Select a clear, readable font for the same reason, increase the point size so it fills the image, and type away. Once you're finished, use the Move tool to put it roughly where you want it—drag it to the center of the image, and automatic guides appear



(as long as you have Smart Guides enabled in "View → Show") to make it easier to perfectly centralize it [Image B].

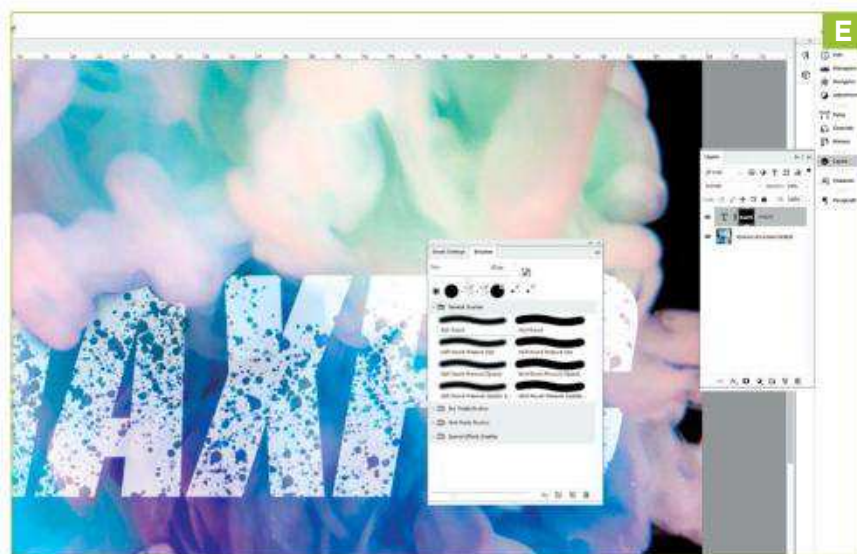
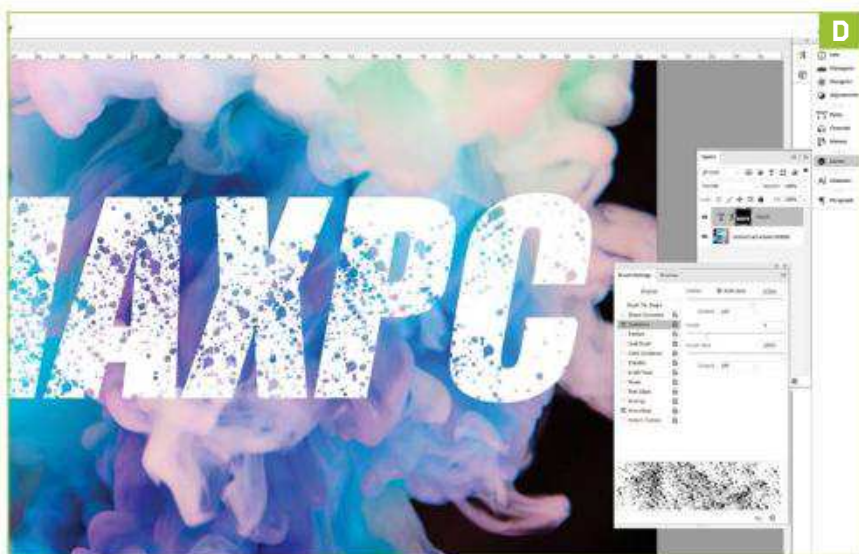
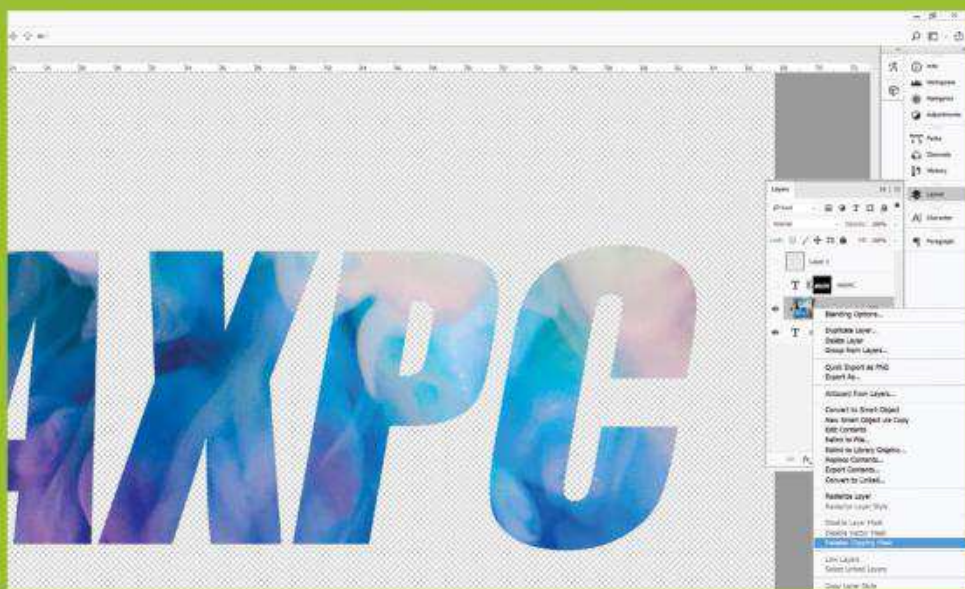
4 MASKED SELECTION

Photoshop makes Layer Masks from selections, so make sure your text layer is selected, and choose an automatic selection tool—we chose the Magic Wand [Image C]. Select your first letter, then hold Shift to select the other letters. Now, when you click the "Add Layer Mask" button at the bottom of the Layers palette—it looks like a dark rectangle with a pale circle in it—you'll see the mask appear next to the layer thumbnail in the palette.



CLIP THE LAYERS

There's another type of mask—the Clipping Mask—that works slightly differently. Place a text layer below a layer that's filled with an image or pattern, and right-click the top layer. Select “Create Clipping Mask” from the menu, and you'll find the pattern is now only visible inside the text itself. A small arrow appears on the layer's entry on the palette, pointing down from one layer to the other, to show what's happening. The layers retain all their information, despite much of it not being visible—so you can use the Move tool to move the pattern within the text, and to move the text layer on top of the pattern. You can continue to edit the type, too, if you change your mind in the future.



5 PAINT IT BLACK

A curious property of Layer Masks is that, if you paint on them using black, they melt away, turning into holes through which the underlying layer can be seen. Make sure the mask is selected in the layer's entry in the Layers palette, then choose a scattered brush from the Brushes palette or the drop-down at the top-left. Make it a suitable size, and you can create a splattered mud effect. The Brush Settings panel—from the “Window” menu—is useful to control the amount of scatter, and avoid building up a repeating pattern, which would look unnatural [Image D].

6 FADE AWAY

To bring parts of the background image in front of the text, you've got a couple of options. You can carry on painting on the Layer Mask with a variety of round brushes [Image E], carving away portions of text to let the underlying layer through, and giving the impression they are in front. If you do this, decrease the opacity of your text layer using the slider on the Layers palette to make it easier to see the background layer beneath. This way, you can follow the contours of the smoke, powder, interstellar plasma, or whatever. If painting with black removes parts of the image, painting with white has the opposite effect. You can reset Photoshop's colors to black and white by clicking the small black/white overlapping squares above the main color swatches, and switch them using the 90-degree curved arrow. Bring the opacity slider up to 100% to see the full effect, or leave it slightly faded if it looks good that way.

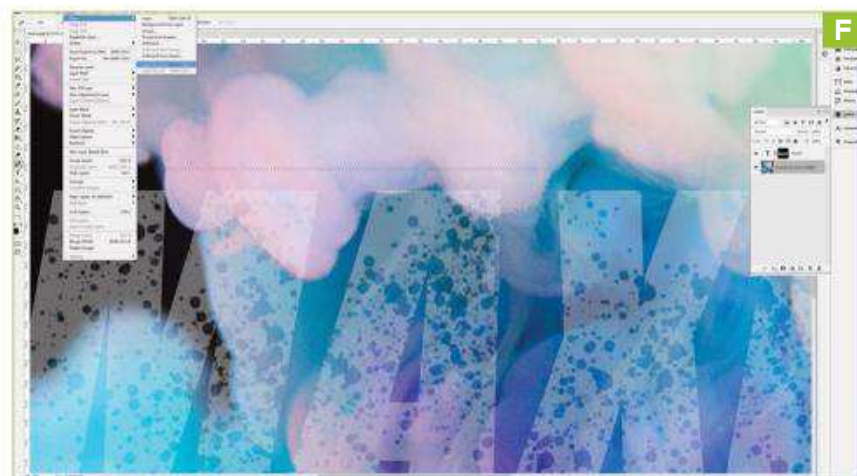
7 SELECT AND COPY

The alternative method is to slice your image up using selections and layers. Select the areas of your background

image that need to be in front of the text—we used the Pen tool to draw a path, then converted the path into a selection using “Load Path as a Selection” from the bottom of the Paths palette, but you might be lucky enough to be able to use something like the Quick Selection tool without it going crazy and selecting half the image; it depends on the photo—and choose “Layer → New → Layer via copy” [Image F]. This copies the selected pixels to a new layer, which you can then drag to the top of the stack in the Layers palette, moving it in front of your text, and partly obscuring it.

8 FINISHING TOUCHES

Lastly, save your work as a PSD file so you can come back and edit it later, and use “Layer → Flatten” to merge all the layers into one, before exporting it as a JPG or PNG for printing or sharing. ⚡



Create Your Own Macro Keyboard

YOU'LL NEED THIS

A SECOND KEYBOARD

This needs to be a different model from your main keyboard.

INTERCEPTION

Download the software from <http://github.com/oblita/Interception>.

AUTOHOTKEY

You can grab the app from <http://autohotkey.com>.

WINDOWS IS, AT TIMES, an annoying and obstinate thing. As in the case we're looking at here: You can plug two keyboards into your Windows machine, and it merrily recognizes them both, but without a little hacking, there's no way to get Windows to see them as separate entities. Type on your second keyboard, and it behaves just like the first. Luckily, we have the solution in the form of Francisco Lopes's Interception (www.oblita.com/interception.html), an app often used by the flight sim community to add buttons and switches to virtual cockpits.

Interception can be tricky, so we're using another tool to simplify its configuration, and once we've isolated the inputs from our second keyboard, we can pump them in to automation platform AutoHotKey to have them trigger more complex macros and functions. But what will you do with yours? You could build a cheap alternative to, say, the \$80 Razer Tartarus V2 [Image A], adding shortcuts for *DOTA* or your favorite MMO, or remapping keys of awkward games. You could line up the core key commands of your video editor, DAW, or streaming host. You could set your second keyboard to automatically type memes or Twitch emotes. Whatever works for you. —ALEX COX



1 PLUG IT IN

Before we even begin with the software, let's get the hardware prepared. The first bit is simple: Grab a second keyboard and plug it in. Note that this needs to be a keyboard from a different manufacturer, or at least a different model, from your current typer, because we'll be intercepting its distinct hardware ID, and if both keyboards share the same HID, you end up locking up both of your input methods

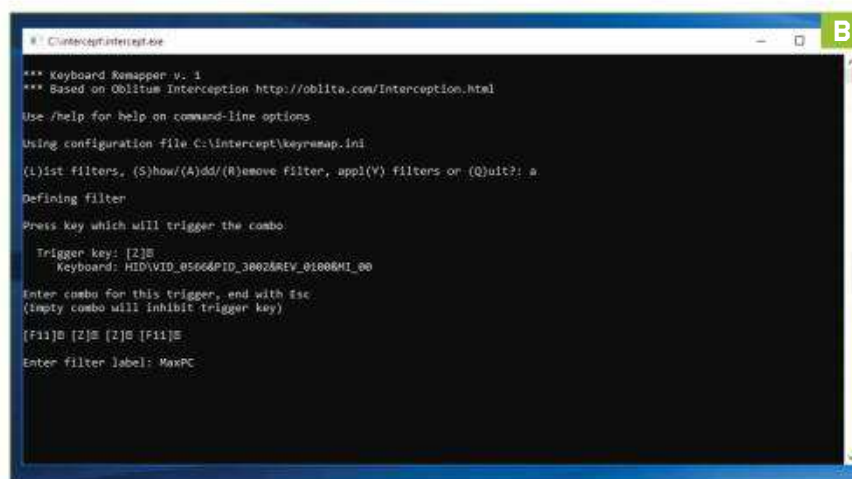
into macro mode. Test it now: You should be able to type normally on both keyboards. Windows may not be friendly when it comes to telling them apart, but it's pretty sharp at handling USB devices. Give it some credit.

2 INSTALL INTERCEPTION

Head over to <http://github.com/oblita/Interception>, go to "Releases," and download the latest package from the top link. Unzip it into a folder. You need to install this package in an administrator-level command prompt. To run this, type "cmd" into the Cortana search box on your taskbar, right-click the "Command Prompt" link above, and select "Run as administrator." Head over to the folder where you unzipped Interception, move into the "command line installer" directory, and run `install-interception /install` to suitably ensconce it. Restart your machine.

3 INTERCEPT IT

Now we need the similarly named but distinct Intercept, which hooks on to Interception, and helps with the actual keyboard remapping portion of the exercise. Download it from <http://bit.ly/2IMsYER>, extract its contents to a folder, and run the application within to start interactive mode. Hit A to add a filter, which also generates its default configuration file. Now hit the key (on your second keyboard) that you'd like to map to something else—if you're following along exactly, go with Z. After this, at the "Enter combo" prompt, you need to define the input you'd like to

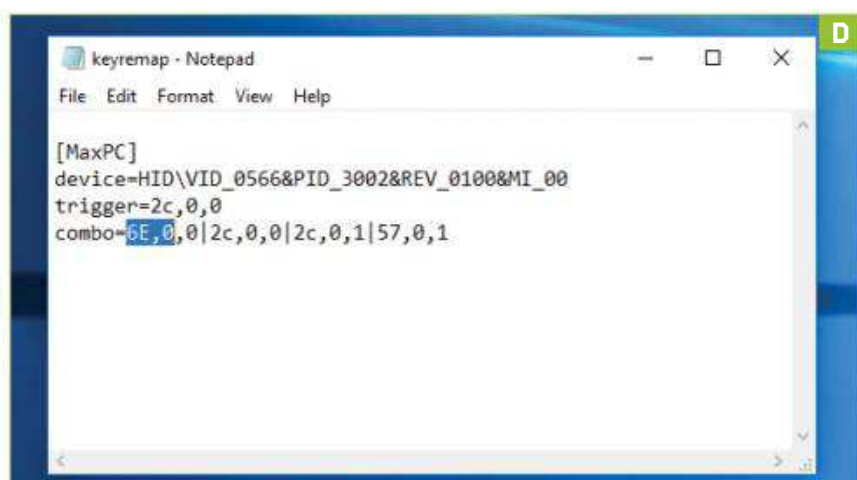


map to it. This includes key press and key release events; if you wanted to simply map it to a different key, you'd press and hold it before hitting Escape, but we're going to do something slightly different. Carefully press F11, press Z, release Z, then release F11 [Image B], before hitting Escape. Label your shortcut however you'd like for now.

4 EDIT THE INI

Here's a fact that's almost been lost in computing history: Your keyboard has 24 logical F-keys, even if, unlike the 122-key Model F terminal keyboard [Image C], it only offers physical keys for the first 12. We're going to use the mysterious F23 as essentially a new meta key,





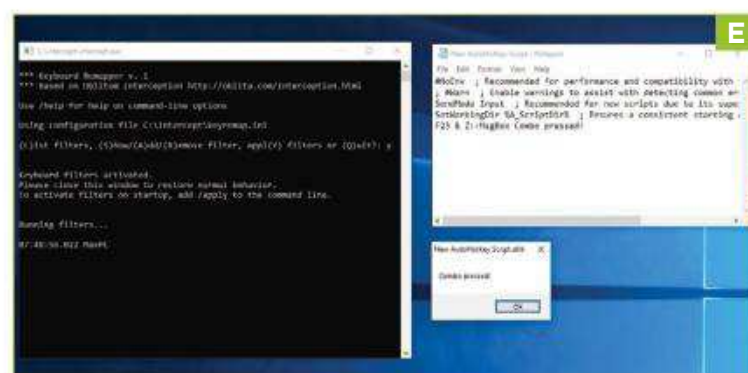
listening out for it later on in AutoHotKey to trigger our macros without any affecting normal operation. Since you can't press it by normal means, you need to open up the keyremap.ini file that's been created in the Intercept directory, and tweak it manually. On the "combo" line of the shortcut you just created, change each instance of "57,0," (the scancode for F11) to "6E,0," (the scancode of F23) [Image D]. Save the file, close your Intercept window, then rerun it, and hit Y to start listening for the key. When you now hit Z on your second keyboard, you should see the combo detected in the Intercept window.

5 GO AUTO

With your second keyboard now recognized, and Intercept running to sniff out your special key combo, let's check that it's working with AutoHotKey. Head over to <http://autohotkey.com>, download, and install. Once it's in, right click your Desktop, and select "New → AutoHotKey Script," then right-click the new file, and select "Edit Script" to open it in Notepad. Now, looking at the basis of even a blank script, we're not going to argue that AHK isn't a bit intimidating—it carries a steep learning curve—but it is, at least, very well documented, and proving it works is incredibly easy. Just add the line `Z & F23::MsgBox It works!` to the bottom of the file, save it, then right-click it, and select "Run Script." Hit the Z key on your second keyboard, and you'll see a message box pop up [Image E]; try it on the first, and the same thing won't happen.

6 MAKE IT NEAT

Since we've settled on F23 as our modifier key, it's time to create a new AHK script, and set up a straightforward statement that listens for it. Start with the line `#SingleInstance force` to make sure its contents retrigger when a different key is pressed, then, below, insert `#if (getkeystate("F23", "P"))`. This says to listen for the contents of the "if" statement if the F23 key is pressed; add the line `F23::return` beneath, so that the statement exits when F23 is no longer pressed. Add a blank line, then a line simply reading `#if` to close off the statement. In between, you can now insert your various triggers, without needing to reference



F23—this has the added benefit of making AHK listen for an extra key press (for example, you could add a `RightShift & Z::` instance), since it's usually restricted to two in a single statement. If you want to use more than two keys in addition to F23, nest an extra "#if" statement inside.

7 COMPLEX ACTIONS

You can use Intercept to make as many combos as you like, and there are other options; you could create a trigger, and then type out a string of characters, swap individual keys around for your own custom layouts, or apply your shortcuts to any keyboard you like—there's no reason to stop at two if you need three, four, or 14. If you need a timed macro, though—if you want to trigger an action based on a cooldown in *WOW*, for example [Image F]—you need to use a subroutine and a "gosub" command in AHK. First, set your key to jump to the subroutine with something like `Z::gosub Foo`, then, at the bottom of your AHK script, define the subroutine with `Foo:` and put a `return` statement below it. Between, you can insert the actions you wish to take. Try using `send` and `sleep` commands to press the appropriate keys with the appropriate delay between. ⏻



USES OF AUTOHOTKEY

See AutoHotKey's extensive manual (<http://autohotkey.com/docs>) for a full description of its features and how to use them, and check out the "Script Showcase" section for some more advanced Windows functionality, the majority of which can be fudged to work based on your custom triggers. You can do some interesting stuff, such as adding

a screen magnifier, pulling out dialog boxes into semi-transparent always-on-top windows, tweaking your volume with self-made media keys, and much more.

When you start coding your own, try tying your macro keyboard to commands such as "Run," to fire off programs—try `Run, notepad.exe` or `Run, https://microsoft.com`—or "Send," which sends

a key stroke, to extend your intercepted key strokes into more complex strings or combinations. Pay attention to the distinction between key up and key down commands; if you want to hold one key while you press another, put the key down event first, insert your key presses afterward, and add a key up event later on to release the original key.

BUILD IT

ZAK STOREY, DEPUTY EDITOR



Home Theater Dreams

Always up for a challenge, our HTPC has tight hardware constraints within an even tighter build

LENGTH OF TIME: 2-3 HOURS

LEVEL OF DIFFICULTY: MEDIUM

THE CONCEPT

WELL, HERE WE ARE: our first attempt at an HTPC stylized build. We knew from the get-go that the Phanteks Shift was the case of choice for our home theater aspirations. Having worked with its cases extensively over the last few years, we've learned that the top-quality materials and consideration toward builders ingrained into every facet of Phanteks's design make most builds in its cases a cakewalk. Knowing we'd be working in a tight chassis with an ITX system meant we would definitely hit problems, so having a quality case was an important first step.

The Shift comes in two variants: the shorter, stubbier standard Shift, and the longer, water cooler supporting Shift X. As our build is aimed at longevity, rather than brute power, the Shift X is a little overkill for what we had in mind. Air cooling is the name of the game, along with designing a compact machine that can happily sit next to a set-top box or amplifier, and not be that noticeable.

But why build this machine in the first place? What can an HTPC

provide that a good smart TV can't? The answer? Control and versatility. For us, it's the control element of an HTPC that's most appealing. You've probably seen it: a smart TV that gets slower over time as the hardware ages, the storage fills up, and you're just left with a frustrating menu system that chugs away, wasting your time. Our media consumption is no longer as on-demand as we've come to expect.

If you build your own home theater PC, however, you know exactly what you're getting, and if you have any issues, you'll likely know exactly what the problem part is. Being able to choose your spec is a big deal. Couple that with the fact that you can run practically any streaming service on a Windows PC via a web browser, and load your own media from masses of affordable local storage, or even from a network attached device, and the PC quickly pulls ahead, more so than a Raspberry Pi, Fire Stick, or anything else, for that matter.

The only downside? It requires a lot of setup. So, we'd better begin.



SPEC OPS

HOW DID WE SPEC out this rig? Well, we didn't have a budget in mind. We knew we wanted a processor with integrated graphics with HDCP 2.2 support (for 4K streaming), and we knew we wanted a system that had a dedicated GPU, too, so we could do a bit of couch gaming on the side with Steam's big picture mode, but that was about it.

The decision, therefore, was: AMD or Intel? Both offer processors with integrated GPUs, but in seriously different configurations. Intel has the integrated GPU buried within all of its lineup, while AMD only has it in two parts, the Ryzen 3 2200G and Ryzen 5 2400G, both of which lack the full complement of PCIe lanes for a dedicated GPU (running eight dedicated PCIe 3.0 lanes, as opposed to the full 16).

We decided to go with AMD's Ryzen 5 2400G. We had the option to run an Intel Core i3-8100, but for the sake of trying something new (and seeing if AMD's HDCP 2.2 driver had been launched), we went for Team Red. That's not to say the 2400G is a bad part; it's an affordable option, that packs a punch when it comes to integrated performance. We chose to couple it with an Asus GTX 1060 3GB, again with HDCP 2.2 support. It should be more than enough to power through any of our local co-op titles, and maintain a steady 60fps in the process.

As for memory, we've gone with a simple 8GB (2x 4GB) HyperX Predator DDR4 3,000MT/s kit. And for storage, rather conservatively, and something of an "on the fly" adjustment, due to chassis limitations, we've picked a single 1TB Samsung 860 Evo M.2 drive, the same one we featured in our liquid-cooled ITX build a few issues back.

It's also worth noting that for this build we're running with an X470-I motherboard. In reality, we'd recommend you instead go with the Asus ROG Strix B450-I Gaming, especially in an ITX build—the boards are identical bar name and chipset, and the B450-I should save you a sweet buck in the process.

INGREDIENTS

PART		STREET PRICE
Case	Phanteks Evolv Shift Satin Black	\$110
Motherboard	Asus ROG Strix X470-I	\$205
CPU	AMD Ryzen 5 2400G	\$160
CPU Cooler	AMD Wraith Spire RGB	\$45
GPU	Asus GTX 1060 3GB Dual	\$236
Memory	8GB (2x 4GB) HyperX Predator DDR4 @ 3,000MT/s	\$120
PSU	Be Quiet! SFX L 600W PSU	\$120
Storage 1	1TB Samsung 860 Evo M.2	\$288
Storage 2	N/A	\$0
OS	Windows 10 Home 64-bit	\$100
Total		\$1,384

1

ALL HANDS ON DECK

WOULD YOU BELIEVE that when we unpacked our chassis, it came with instructions on how to empty the actual cardboard box? Yep. Then further instructions on how to disassemble the case. That's a first. But, to be fair, it's not that obvious. This baby has a pop-hinge top cover (which hides all your cables from the rear I/O), then six individual captive thumbscrews inside, two for each panel (bar the rear-most panel). Loosen those screws, gently grab the tempered glass side panel, and pull it up to pop it out of its secure housing. You might find some of the screws are a little too tight—we had to remove one entirely because it must have been tightened too much in the factory.



2

AMD PROCESSOR INSTALLATION

AHH, THE PGA GRID—how wonderful you are. To install any of the latest Ryzen processors on the AM4 platform, simply lift the retention arm up from the CPU socket, carefully slot the Ryzen chip into place, making sure to align the golden triangle corner on the chip with the one on the socket, push down until it fits snugly, then lower the retention arm back down until it clicks into place. Your processor is then secure. On the Asus ROG Strix-I mobos, there's also an M.2 slot located under the ROG logo, just south of the chipset. Use a tiny screwdriver to undo the two screws on the bracket, install your M.2 drive, then resecure back down, remembering to remove the film from the thermal pad on the underside of the M.2 heatsink (aka the big bit of metal with the ROG logo on it).



3

PRIORITIES

FOR THIS BUILD, we're flipping things on their head by installing the motherboard first. We installed our Wraith Prism cooler outside the chassis first, along with the memory, then installed the motherboard directly into the case, before the PSU. Things are a little tight in this chassis, so getting the mobo in first is of paramount importance. The Shift also comes with a PCIe riser cable, which needs plugging in to your PCIe slot. It's removable, and you can shift the position of this to the other side, but more on that later. Also, that Phanteks logo just above the rubber grommets? That's actually a rotating bracket, secured by magnets that you can rotate down, which makes installing your cables a little easier. Neat, huh?



4

GPU INSTALLATION

AND HERE WE HAVE THAT PCIe bracket/GPU installation we mentioned. It's secured in place at the back by a single thumbscrew, which can be a bit awkward. The bracket itself, however, can be adjusted, and slides up and down, to give more PSU clearance, or allow for better airflow. There's a single 140mm fan up top, which provides either exhaust or intake air for both your CPU and your GPU compartment. It is possible to reorient this bracket, so it's facing the other way, but Phanteks only recommends you do this if you're liquid cooling, otherwise airflow becomes an issue. You can also see the ton of mounting options at the bottom of the chassis for radiators and AIOs.



5

THE LITTLE DETAILS

IT'S THE EXTRA EFFORT that Phanteks puts into its case design that always amazes us. Take installing the PSU, for instance. Phanteks has made a tiny cutout in the aluminum chassis here to give you an easier time when tightening one of the screws for the PSU. It's a tiny detail, but one we very much appreciate. There's a full-sized rectangular cutout on the other side for the other screw, too. It's also worth noting here that due to the PSU cable pass-through, you're going to want to make sure the power switch on your PSU is set to on before both installing the cable and securing the PSU itself.



6

SFX WOES

THIS IS THE ONLY PLACE we wish Phanteks had given us an extra inch (although there is the Shift X...). Modular SFX power supplies in this build are a nightmare. Install the cables first, and you can't fit the PSU in place; install them afterward, and there's not enough room to even push them in. On top of that, the rubber grommet bracket, with the magnetic folding Phanteks cover, is annoyingly pop-riveted into place. If you could remove that, or temporarily move it upward, it would make PSU installation so much easier. To get around this, we ended up pre-installing the cables into the PSU before securing it, then pushing the cables down as much as possible, in an attempt to flatten them. We then removed one of the rubber grommets from the cable pass-through to give us enough wiggle room to slide the PSU in and secure it in place.





- 1 We'll be honest: This CPU heatsink is probably a bit too close to the glass window. We're running the 140mm fan to the right as an intake to compensate.
- 2 Another intake fan in the bottom here would have been ideal to feed both the system and the GPU.
- 3 There are two 2.5-inch SSD mounting brackets located here. For anyone after more affordable storage, you'd need to source some 2.5-inch HDDs.
- 4 Some cable ties would have helped solve this cable mess, no problem.

CAPTIVATING FUN

WHAT WE LOVE ABOUT the Shift is its versatility. It's such a neat little case to work in. It has its limitations, sure, but for those who need the additional storage or space, you can always opt for the larger Shift X instead.

Weirdly, it's one of the few cases we've had to tinker with more than we thought we'd need to. For instance, the motherboard went in and out three times, the PSU took us the best part of an hour to figure out how to mount it in the chassis, and working out how to use the storage and where to stick the GPU was more time-consuming than we'd anticipated.

What would we change? More cooling, for a start. By default, the Shift comes with a single 140mm fan configured as an exhaust, next to the motherboard and the GPU. In an ideal world, we would have left that, and installed two intake fans in the bottom instead. For a standard PC build, we'd have likely also gone for a liquid-cooled 120mm AIO for the CPU instead. That way, we'd have less to worry about when it comes to keeping the CPU cool, and the AIO would be in the bottom compartment. Sticking with air cooling, though, a slimmer CPU tower would be on the cards; having one right up against the glass like that isn't conducive to good airflow.

Then there's the motherboard and CPU combo. Would we stick with AMD? If we were to build this for ourselves, probably not. We're not after masses of cores here, or integrated GPU performance—more the ability to encode

with HDCP 2.2. The reality is, we'd probably take out the Ryzen 5 2400G and replace it with the Intel Core i3-8100 we mentioned earlier, and pair that with something like the Asus ROG Strix H370-I (\$140). It's far cheaper than the AMD variant used, comes with Wireless A/C, HDMI, DisplayPort, optical audio out, 5.1 audio, and dual Ethernet ports. Connect one of the latter to your in-house NAS, and you nullify the need to have additional drives.

Speaking of storage, we're still not convinced about those two 2.5-inch mounts to the left of the mobo, especially with the PCIe

card being as flexible as it is. There is potential in the Shift to mount a 3.5-inch hard drive in the bottom of the chassis, but you would need to make sure it's secure if you were to reorient the chassis or lay it on its side.

As for performance, it's a meaty little rig, even with the meager 8GB of DDR4. Storage is zippy, 1080p gaming performance competent enough (despite the lack of 16 PCIe lanes), and overall thermals are relatively low. We're certainly happy with it, and it should make a nice little media streamer for our office lunch breaks. ⏻

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	1,152	775 [-33%]
CrystalDisk QD32 Sequential Read (MB/s)	3,400	554 [-84%]
CrystalDisk QD32 Sequential Write (MB/s)	1,720	506 [-71%]
PCMark 10 Express (Index)	60	56 [-7%]
Rise of the Tomb Raider (Avg fps)	46	42 [-9%]
Total War: Warhammer II (Avg fps)	39	36 [-8%]
3DMark: Fire Strike (Index)	11,101	10,241 [-8%]
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%		

Our zero-point consists of an AMD Ryzen 5 1600, 16GB of Crucial Ballistix Sport LT @ 2666, an EVGA GeForce GTX 1060 3GB, and a 250GB Samsung 960 Evo M.2 PCIe SSD. All tests were performed at 1080p at the highest graphical profile.

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Intel Core i7-8086K

Speed is power!

WHERE DO WE EVEN BEGIN with this? Seriously. From the outset, for those who are already on Intel's eighth-gen platform, the 8086K processor simply doesn't make any sense. In short, it's a pre-binned Intel Core i7-8700K, released to commemorate the fortieth anniversary of the x86 architecture. There's a limited run of them, too—around 50,000 in total—and that's all there really is to it. There's nothing new here. Apart from the guaranteed 5GHz turbo out of the box, of course.

Open and shut case, then? It's a dud? Not by a long shot. This processor is nothing short of awe-inspiring, extraordinary, unimaginable. Take your pick from our whimsical adjectives: It's a phenomenal piece of history, and it tells a story. It takes the very best of what Intel can muster today, skimmed from the top of those 8700K silicon wafers, and honors its predecessors from the last 40 years of processor development, across both AMD and Intel. From 29,000 transistors

on a 3,000nm process in an area 33mm² to around 5.6 billion transistors (rough guess—Intel doesn't make it public anymore) using a 14nm process, with a die that's 151mm², the last four decades of CPU evolution have been incredible. To give you some perspective, if that were represented on a *Maximum PC* bar chart, it would be an improvement of 19,310,245 percent.

Time for some benchmarks. At stock, the 8086K scored 212 points in Cinebench R15 single, versus the Core i7-8700K's 203; 1,630 in multi versus 1,549; and it completed Fry Render in 128 seconds, compared to the 8700K's 133. Power draw under load was 2W higher than its lower-clocked sibling, and that's about it. So, at stock, it's undeniably a better processor—but for \$75 more? We're not so sure.

What's so impressive about it, then? It's that untapped potential inside. At stock, the Core i7-8700K and the 8086K have very similar turbos—both max out at 4.3GHz across all six cores, with the 8086K taking the lead on the single core running at 5GHz instead of 4.7GHz. By just adjusting the multiplier, you can easily get 5GHz across all the cores.

HOT STUFF

Problem is, there's a huge issue with temperature. At stock, under load, it easily hits around 82 C with a 360mm AIO. Try to aim for something like 5.3GHz, and you'll run straight into that 100 C TJMax. That said, 5.2GHz across all six cores is still a 900MHz increase, and pumps out some impressive numbers, too, even if you're skirting around that 90 C mark, with

1,682 points in Cinebench R15 multi, and 218 single-core.

But this isn't a normal processor, nor a normal review, and we knew our 8086K had more to give. So, we took the chip, grabbed our trusty Der8auer Delid Die Mate, took the heat spreader off, and replaced the thermal paste with some Thermal Grizzly Conduction Liquid Metal, before gluing it all back together. The result? Temperatures at 5.2GHz dropped by a staggering 19 C, from 90 C down to 71 C.

We then pushed for 5.3GHz again, this time upping the voltage to 1.44V, and successfully benchmarked it, with temps reaching 80 C on the hottest core. The chip was stable, and achieved 1,713 points in Cinebench R15, and 229 on the single core. We knew from the industry that only the top 14 percent of 8086Ks could achieve that frequency, but the itch to go further was still there. Our final overclock was achieved at 5.4GHz across all six cores, at 1.48V. It scored an incredible 1,753 points in Cinebench, and 233 points single-core, with a maximum package temp of 86 C. To be honest with you, it probably has more to give, but we just don't have the cojones to push it any harder.

So, what is this chip? And who is it for? It's a one-off, a limited-edition piece of history. It's the true king of the original Skylake architecture, and arguably should be the last of the breed. Whether that will be the case or not is still to be decided, especially given Intel's current progress with 10nm. Is it for you? Well, that depends on how far you're willing to go for the sake of performance and glory. It's not a smart choice, for sure, but it's certainly a satisfying one. —ZAK STOREY

PROCESSOR BENCHMARKS

	Intel Core i7-8086K	Intel Core i7-8700K	AMD Ryzen 7 2700X
Cinebench R15 Single (Index)	212	203	180
Cinebench R15 Multi (Index)	1,630	1,549	1,814
Tech ARP's X264 (fps)	35.98	33.28	31.71
Fry Render (m:s)	2:08	2:11	2:14
AIDA64 Memory Latency (ns)	48.1	48.1	68.4
AIDA64 Memory Bandwidth (MB/s)	46,451	46,425	46,506
Power Draw Idle/Load (Watts)	69/200	65/198	91/221
Total War: Warhammer II @ 1080 (fps)	84	84	76
Ghost Recon: Wildlands (fps)	61	61	55
Middle Earth: Shadow of War (fps)	96	95	86
3DMark Fire Strike (Index)	19,563	19,476	17,855
Maximum Overclock at Voltage (GHz @ V)	5.4 @ 1.48	5.2 @ 1.43	4.2 @ 1.45
Price to Performance (Index)	3.84	4.43	5.50

Best scores are in bold. Our test bed consists of an Asus Maximus X Hero, 16GB (2x 8GB) of Corsair Dominator Platinum, an Nvidia GeForce GTX 1080, and a Samsung 850 Evo 500GB SSD. All games were tested at 1080p on the highest graphical profile, with average fps noted.

VERDICT

9

Intel Core i7-8086K

EMPEROR Incredible potential performance; limited edition; the perfect overclocking chip.

SERF Not worth it at stock; needs a delid.

\$425, www.intel.com

SPECIFICATIONS

Base/Turbo Clock	4/5GHz
Cores/Threads	6/12
Lithography	14nm
Cache	L3 12MB
Memory Support	64GB DDR4
Memory Channels	2
Max PCIe Lanes	16
TDP	95W



Fourth-gen Skylake, anyone?

Razer Blade 15

Small, solid, strong

IT'S BEEN JUST OVER five years since Razer introduced the original Blade laptop. At the time, it was the gaming answer to the ever-popular MacBook form factor—14-inch body, aluminum chassis, solid clamshell design. Compared to its contemporaries, the Blade was minuscule, but gaming laptops have slimmed down since, culminating in the Max-Q design seen in the best laptops of the last year or so.

With the Blade 15, Razer has caught up with the competition in terms of what makes a great gaming laptop. Solid build, slim body, elegant design, long battery life, thin bezels, 144Hz screen, and internals powerful enough to play the latest games. That means an Intel Core i7-8750H paired with an Nvidia GeForce GTX 1070 Max-Q.

What sets the Blade 15 apart is the details. Its aluminum body is the most solid and flex-resistant of all the laptops we've tested lately, and it's the thinnest, too, by about half a millimeter. Of course, that half-millimeter difference is mostly negligent in terms of perception—more impressive is the overall solid feel of the body, which Razer says is CNC-milled from a single block of aluminum. Opening it up, the touchpad is larger than its peers, and the keyboard is flanked by large speakers.

The keyboard, however, gave us a few problems. The keys feel good to press, suitable for both typing and gaming; our problem came with the layout, which in addition to missing a number pad (forgivable, considering the space constraints), repositions the up-arrow key between right-shift and forward-slash. If you're used to using right-shift and forward-slash for question marks,

prepare to mess that up. Our other issue is with the touchpad—its large size caused us to accidentally tap it while typing.

Razer cultivates its brand with a gaming-first mentality, which shows: Despite a slightly thinner design than its peers (17.2mm thick compared to the MSI GS65's 17.7mm), the Blade 15 performs better in our gaming benchmarks. It averaged 92fps across *Rise of the Tomb Raider's* three-part benchmark, managing 144fps in the Mountain Pass, 83fps in Syria, and 78fps in the Geothermal Valley. That's much closer to our zero-point's 99fps (powered by a non-Max-Q GTX 1070) in *RotTR*, compared to the mid-80s scores of the GS65 and Gigabyte's Aero 15X. *Total War: Warhammer II* and *Ghost Recon: Wildlands* produced scores either in line with or a slight step up from the GS65 and Aero 15X—59 and 44fps respectively—though the difference was more in the realm of 3–4 frames, as opposed to 10-plus.

The Blade pulls those scores off thanks to a vapor chamber cooling solution connected to the CPU and GPU. It keeps the internals from throttling under extended load, and stops the outside of the Blade getting too hot to handle during extended gaming sessions. After a lengthy stress test, we measured temperatures of around 54 C at the hottest points—above the keyboard—but the area around the WASD keys remained in the realm of a temperate 38 C. The bottom warms up to a point that's uncomfortable for on-lap use, but we've yet to meet a gaming laptop for which that wasn't the case.

The Razer Blade 15 delivers absolutely everything we want in a gaming laptop,

in one of the best-designed bodies we've ever seen. The build quality is top-notch, and gaming performance matches. The downside, of course, is its price. The Blade 15 starts at \$1,899, but that's for a GTX 1060 Max-Q GPU and a 60Hz screen. The GTX 1070 Max-Q models, like the one we tested here, start at \$2,399, with more expensive options if you want a larger SSD or a 4K panel. The Blade is probably the best-looking gaming laptop we've ever tested, but near-identical performance can be had from MSI's GS65 Stealth for a few hundred dollars cheaper. So, choose your weapon wisely.... —BO MOORE

VERDICT

9

Razer Blade 15

CUT-THROAT Exceptional build quality; thin and light; great gaming performance.

DULLED EDGE No Ethernet port; awkward keyboard layout.

\$2,399, www.razer.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	743	1,082 (46%)
CrystalDisk QD32 Sequential Read (MB/s)	563	2,090 (271%)
CrystalDisk QD32 Sequential Write (MB/s)	133	2,064 (1,452%)
3DMark: Fire Strike (Index)	13,202	13,039 (-1%)
Rise of the Tomb Raider (fps)	99	92 (-7%)
Total War: Warhammer II (fps)	62	59 (-5%)
Tom Clancy's Ghost Recon: Wildlands (fps)	48	44 (-8%)

Our laptop zero-point is the Asus GL502VS-DS71, with an Intel Core i7-7700 HQ, a 8GB GTX 1070, and 16GB of DDR4-2400. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

Processor	Intel Core i7-8750H @ 2.2GHz
Graphics	Nvidia GeForce GTX 1070 Max-Q
RAM	16GB DDR4-2667
Screen	15.6-inch 144Hz Tn
Primary Storage	256GB NVMe M.2 SSD
Keyboard	Anti-ghosting with Razer Chroma backlighting
Cooling Solution	Twin vapor chamber + dual 44-blade slim fans
Battery	80Wh lithium-ion polymer battery
PSU	230W adapter
Total Weight	4.63lb



The best performance we've
seen from this generation's
thin-and-light gaming laptops.



It gets a little hot under the collar under load, but it's still a great buy.

Asus ZenBook 3 Deluxe UX490UA

Super-thin and light, but stumbles if heavy lifting

ULTRABOOKS MAY HAVE been with us for over six years now, but it still feels like we haven't quite hit the perfect balance of performance in a slimline package. One brand that has gotten intriguingly close to this portable nirvana is the ZenBook from Asus, and this latest iteration looks to build on the strengths of previous models, with bang up-to-date components, and an even sleeker chassis. Color us interested.

The headline component on the spec sheet is the processor, and in this machine that's just half an inch thick, you'll find a quad-core, eight-thread Core i7-8550U (Kaby Lake R). This chip has a base clock of 1.8GHz, but generally runs quicker, thanks to the joys of turbo boost. But how much it boosts is a bit of a contentious affair: Intel says it'll peak at 4GHz, Asus says it'll run at anything up to 3.7GHz, while in testing we witnessed it reach 4GHz under heavy workloads (our benchmarks).

This does lead to our biggest problem with the ZenBook 3 Deluxe, though—that 4GHz peak saw the processor temperature hit 100 C, which lead to it throttling back to keep the thermals down. Run benchmarks multiple times in quick succession, and your figures quickly tank, with subsequent results coming in far lower than the last—we recorded a Cinebench R15 score of 450 after a particularly hard benchmarking session; over 20 percent lower than its highest score. Obviously, you're not going to push a machine like this so hard on a day-to-day basis, but by the same token, you'd

be better off settling for a lesser CPU that isn't constrained by the thermal envelope it finds itself operating inside.

The storage side of things is a much more straightforward proposition: This thing flies. There's nothing new about PCIe NVMe SSDs, but laptops still tend to go for SATA drives to keep prices down, so it's refreshing to throw files around on here. Installations are speedy, file copying a breeze, and Windows is smooth in operation. Asus doesn't brag about what drive is being used, although a bit of snooping reveals that it's a Samsung PM961 hiding inside. 512GB is plenty of room for most uses, although you may need to grab an external drive for some workloads, but don't forget that this is USB-C territory (though a USB-A/HDMI dongle is included).

The rest of the specification is reassuringly punchy, with 16GB of LPDDR3 RAM giving your applications plenty of room to work with. The screen is worth spending a bit of time with, because it looks incredible whether you're working, playing back a movie, or trying to enjoy some low-powered gaming. Speaking of which, this isn't a gaming laptop, and we're not going to take any marks away from it for that fact either, but just for your own understanding, you're going to be hard pushed to hit playable frame rates in modern games, even with everything set as low as possible. The Harmon/Kardon audio is reasonable enough, given its thickness, although it isn't going to challenge a decent set of

cans. One oddity here is the webcam—it's merely a VGA model, which seems a bit off given the rest of the specification.

Performance is impressive in the main, particularly given the thickness of the machine. And provided you're not thrashing it constantly, you should find you have more than enough power for most normal uses. We would have liked it to have better battery life, as this is going to struggle to do a full day's work away from the power point, but it's light enough to carry around, and the power brick is tiny enough as well.

Overall, there's a lot to like with the ZenBook 3 Deluxe. It looks good, is well built, packs in some quality components, and is the sort of machine that the PC industry as a whole needs to champion. It's just a shame it gets so hot when you really push it, otherwise it'd be one of the easiest recommendations we've ever made. Even allowing for its shortcomings, this is one of the most impressive Windows laptops you can lay your hands on. —ALAN DEXTER

VERDICT

9

Asus ZenBook 3 Deluxe UX490UA

PRESTIGIOUS Super-thin

and light design; gorgeous screen; comfortable keyboard and touchpad; strong performance...

SACRILEGIOUS ...but throttles under load; unexciting battery life.

\$ 1,299, www.asus.com

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi (Index)	743	535 (-28%)
CrystalDisk QD32 Sequential Read (MB/s)	563	3,215 (471%)
CrystalDisk QD32 Sequential Write (MB/s)	133	1,621 (1,119%)
3DMark: Fire Strike (Index)	13,202	1,005 (-92%)
Rise of the Tomb Raider (fps)	99	4 (-96%)
PCMark 8 (Index)	2,379	3,222 (35%)
Battery Life: Movie Playback (Mins)	183	385 (110%)

Our laptop zero-point is the Asus GL502VM-DS74, with an Intel Core i7-7700 HQ, an 8GB GTX 1070, and 16GB of DDR4-2400. All game tests are performed at 1080p at the highest graphical profile.

SPECIFICATIONS

Processor	Intel Core i7-8550U
Graphics	Intel HD Graphics 620
RAM	16GB LPDDR3 2,133MHz
Screen	14-inch 1080p 100 percent sRGB color gamut
Storage	512GB PCIe NVMe SSD
Keyboard	Full-size backlit, with 1.2mm key travel
Battery	Four-cell 46Whr
PSU	65W USB-C
Weight	2.4lb
OS	Windows 10 Pro 64-bit

Asus ROG Maximus X Formula

We've been taken to tenth-gen heaven

NOTHING SAYS "PREMIUM" like a Formula board. They are the kings of Asus's consumer lineup. Granted the very best features from each generation of mobo design, the Formula is a luxury for those willing to splurge the coin. The tenth iteration of this design ethos has lead to this: a \$350 masterpiece of connectivity, rear I/O, BIOS, liquid-cooling, and armored PCB. And it looks marvelous.

That thermal armor—which was introduced with the TUF series, way back in the Z77 era—is hardly a new concept, and whether it actually reduces overall stress and temps on the PCB is still highly debated. That said, there's no denying just how impressive this thing feels in your



hands. The reinforced backplate alone must weigh half a pound at least.

RGB lighting is subtle, with only four illuminated zones: the now-standard one baked into the rear I/O cover, one outlining the integrated on-board power and restart buttons, one embedded into the chipset heatsink, and the last ones at the ends of each PCIe slot, to give them a little extra pop. It's quite a departure from the trend we've seen over the last few chipsets, and it's far less gaudy.

There's good reason for that. The Formula's true party piece is the OLED display fixed to the middle, just south of the CPU socket. At boot, this small two-inch hexagonal panel shows off the BIOS debug

codes your system's cycling through. It's on login, however, where things get more interesting: Using Asus's LiveDash software, you can show any number of useful statistics, from CPU temps to voltages, clock speeds, and fan RPMs. Or, if you're after something fancier, you can throw your favorite GIF on there, or one of Asus's logos, all pre-programmed into the LiveDash. Admittedly, this isn't the first time we've seen this—the Intel X299 Rampage VI Extreme and AMD X399 Zenith Extreme feature similar displays on the rear I/O cover—but it's a versatile, clean design element that feels right at home in a more consumer-friendly chipset.

Then, of course, we get to performance. Overall, the Maximus X Formula performs well. Cinebench R15 scored a respectable 1,414 points, with the remainder of our CPU rendering tests falling in line with our other results. One thing that did catch our eye, however, was the seemingly excessive power draw under load. At stock, performing our standard looping 3DMark Fire Strike Extended test, we saw power scores clock up all the way to 333W. Now, that's not huge, not when you think about how taxing that benchmark is, but given the fact it's been some time since we've looked in detail at a Z370 motherboard, it was the stark contrast to its AMD counterparts that really caught our eye—it's 55W higher than the same test on our Crosshair VI Hero with the Ryzen 7 1800X. As that has an additional two cores, it just goes to show how much Intel is struggling with this latest generation of chips.

On top of that, Asus mobos still have problems with the auto CPU voltage being way too high at stock. Registering temperatures as high as 72 C under load with a 360mm AIO, it certainly doesn't feel too comfortable. That said, it does mean

you can just throw a ratio at it and be pretty happy. We managed a clean 5GHz without even touching any other settings, although it was drawing 1.3V. Auto-overclock that yourself, and you can get it as low as 1.22V without throttling the chip.

The Formula is the pinnacle of what Asus has to offer today. From connectivity to integrated VRM waterblocks, fancy displays, and more, it truly is the best board you can get for the Z370 platform. But there's a hitch: the price. For the money, it's good value, but do you need all those features, and do you need to pay that much? Well, that's the question.... —ZAK STOREY

VERDICT

9

Asus ROG Maximus X Formula

SUMMIT Huge connectivity; strong performance; aesthetically impressive; OLED display; backplate, armor, and I/O shield.

SEA FLOOR Price; only single eight-pin EPS power; high stock voltages.

\$350, www.asus.com

SPECIFICATIONS

Chipset/Socket	Z370/LGA1151
Form Factor	ATX
Memory Support	64GB DDR4 @ 4,133
M.2/U.2 Support	2x M.2
SATA Support	6x SATA 6Gb/s
Max PCIe Support	3x PCIe x16 (max PCIe x8x8 + 1x4)
Rear I/O	4x USB 3.0, 1x USB 3.1 Type A, 1x USB 3.1 Type C, 4x USB 2.0, Intel Gigabit Ethernet, 5.1 audio, optical audio out, DisplayPort, HDMI, wireless A/C, BIOS reset, clear CMOS

BENCHMARKS

	Asus ROG Maximus X Formula	Asus ROG Maximus X Hero
TechARP's X264 (Avg fps)	32.98	33.91
CineBench R15 Multi (Index)	1,524	1,522
Fry Render (M:S)	02:14	02:13
AIDA64 Memory Latency (ns)	48.1	48.1
CrystalDisk QD32 Read/Write (MB/s)	549/467	551/513
Power Draw Idle/Load (Watts)	48/333	65/336
Total War: Warhammer II (Avg fps)	56	56
Lowest Voltage @ 5GHz (Volts)	1.22	1.23
Maximum OC Achieved (GHz)	5.1	5.1

Best scores are in bold. Our test bed consists of an AMD Ryzen 7 1800X, 16GB of Corsair Dominator Platinum DDR4 @ 3,200 MT/s, an Nvidia GeForce GTX 1080, and a 250GB Samsung 850 Evo. *Total War: Warhammer II* was performed on the Ultra preset at 1440p.

If the display and liquid cooling aren't your jam, try the Maximus X Code.

CRAFT, BUILD, FIGHT, AND EXPLORE IN THIS BRAND NEW MINECRAFT SPECIAL!

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MSI Force GC30

Versatility is
the key to a
good controller

NOW, WE'RE NOT USUALLY a magazine to focus on gaming, because we happily leave that to our sister title *PC Gamer*, but there's no arguing about the fact that the majority of the team here certainly does. It's a great way to while away a few hours at the end of the working day, either relaxing with our buddies, or even (oddly, in our modern age) bonding with family. Over the last 10 years, PCs have arguably cemented themselves at the center of the gaming world. Say what you like about consoles, but you just can't argue with the versatility that a Windows system provides when it comes to that favored technological pastime. Whether it's first-person shooters, racing sims, real-time strats, or just goofy indie platformers, the PC can and does do it all, with an insurmountable armada of exclusives, to boot.

The thing is, there are games out there that don't fit so well with the PC staple of a mouse and keyboard environment. Sure, a good tab-targeting MMO can take advantage of all those extra buttons, but if you're on a budget, and can't afford that full-sized racing cockpit, trying to get your brain around using digital key switches to pilot your decidedly non-digital motorized vehicle of choice is enough to drive any normal human being insane. And that's a principle that can be applied to a whole plethora of genres. Localized co-op games, party games, fighting games, even some RPGs benefit from getting a grip on a decent handheld device.

But who do you go for? After all, by default, surely Microsoft is the safest candidate? You can pick up an old-school Xbox 360 USB controller for a little under

\$30, although it's certainly outdated by this point, and definitely not wireless. Then there's SteelSeries, Razer, and Logitech, all of which offer their own expensive variants. You can even buy bespoke one-off controllers (although these typically skyrocket into the hundreds of dollars, and you do have to question what you're doing with your life at that point).

No, for us, gaming is just part of the reason why we love our rigs, and why we build them. And because of that, we need a controller that's versatile, one that will connect to any and all devices we might have, and do it on a budget. That's where MSI's Force GC30 comes into play. Yep, MSI. Typically associated with mobos and GPUs, MSI's first foray into peripherals hasn't been a bad run at all.

GOOD CONNECTIONS

So, what's so special about the Force GC30? Well, it's the abundance of connectivity that really caught our attention. By default, it comes with a six-foot long cable to connect it to your rig via USB, for those low-powered moments, and a 12-inch micro-USB cable for your mobile devices. Then there's the 2.4GHz wireless dongle, which means you can also connect wirelessly to your PC or any PS3.

On top of that, it's also got a built-in battery, dual vibration motors for haptic feedback, and the usual Xbox controller layout. It even has replaceable D-pad covers if you're not quite happy with the overall feel of the standard cross style.

As for downsides, the overall material used could be a little more premium, and it is a touch small, but apart from that,

there's little to complain about. All in all, it's comfortable, has a whole plethora of connectivity, brings a chunky battery to the game, and comes in at a fairly aggressive price, too. Which brings us on to our last point: Annoyingly, it's sold out across most of the United States, with only limited stock seemingly being moved across the Pacific. At the time of writing, it's currently sold out on Amazon, although you can buy an import from eBay for around \$58, but until MSI actually puts down some hard stock in the States, we're going to have to knock off a point. **-ZAK STOREY**

VERDICT
8

MSI Force GC30
PLAYER ONE Versatile connectivity; comfortable grip; replaceable D-pad; good battery life; excellent price.
PLAYER TWO Limited stock; no Bluetooth.
\$58, www.msi.com

SPECIFICATIONS

Compatible OS	Windows 7/8.1/10; Android 4.1 and above
Interface	USB 2.0
Dimensions	6.14 x 4.13 x 2.46 inches
Battery	600mAh lithium
Battery Life	8 hours
Accessories	D-pad cover, wireless dongle
Cables	6.5-foot USB cable, 12-inch micro-USB cable
Weight	9.9oz

ViewSonic XG3220

Big panel, puny pixels

PUNY PIXELS are an increasingly big deal. The smaller the pixels, the sharper, crisper, and more detailed the display. For devices like smartphones and tablets, pixel density is all the rage. The pixel counts offered by such devices are on the up, while the size of individual pixels shrinks ever smaller.

For the PC, and particularly desktop rigs with large displays, however, it's more complicated. For starters, achieving so-called "retina"-style pixel density on a monitor measuring, say, 30 inches or more would require a monumental pixel count, measuring in the high tens of millions. The kind of pixel grid, in other words, that existing display interfaces can't cope with.

Then there's the minor matter of scaling. With a handheld device, the fact that most of the Internet remains built around bitmaps doesn't matter much. On a large display, the fact that few websites have full support for high pixel density, also known as high DPI, displays is more problematical. Meanwhile, the Windows OS's support for multiple DPIs has improved but remains frustratingly short of truly slick.

That's the context for ViewSonic's latest 32-inch monitor, the XG3220. It's one of a number of displays trying to achieve the best possible compromise between pixel density, desktop real estate, and the realities of DPI scaling. As it happens, it pretty much nails it, in our view. The combo of a standard UHD grid numbering 3840x2160 pixels with a 32-inch diagonal makes for a reasonably dense grid, and thus fairly sharp fonts. At the same time, the generous proportions allow for plenty of options when it comes to scaling. Users with excellent eyesight could opt for 100 percent scaling, and thus no issues at all with bitmaps and legacy aspects of the Windows interface. Everyone else can go for 125 to 150 percent scaling, and still retain a generous amount of desktop space.

Of course, all of that applies to every 32-inch UHD monitor. Is there anything that marks the XG3220 as special? The answer is affirmative, but not always for the better. ViewSonic has opted for a VA panel, where most incumbents in this part of the market favor IPS. The upsides include rich colors and excellent static contrast. This LCD screen achieves a 3,000:1 ratio between light and dark, without recourse to active backlighting or local dimming.

The VA panel also contributes to the XG3220's advertised HDR10 compatibility. Which is where the wheels begin to come

off. While it does offer wide color gamut support, including 99 percent of the sRGB color space, that's as far as the XG3220's "HDR" capabilities go. With no local dimming and a peak brightness of 300cd/m², pitching this as an HDR display is a stretch. It's confusing, it devalues the notion of HDR, and we wish manufacturers wouldn't do it.

The other issue related to the VA panel is pixel response. ViewSonic has included a multi-step pixel overdrive option in the menu, but even at its most aggressive setting, ghosting and blurring is very apparent. The panel is also limited to 60Hz refresh, where 120Hz and up is becoming de rigueur for serious gaming screens.

The saving grace is the XG3220's relatively accessible price point. The reality of the current monitor market is that no single screen can give you everything. You can't have 4K resolution combined with zippy responses and high refresh for around \$600, that's for sure. So, ViewSonic's latest is far from perfect. As a gaming monitor, it's fairly flawed. But it's still a large and appealing 4K monitor, and it isn't mega money. So, depending on your precise needs and budget, it may still hit the spot. —JEREMY LAIRD

VERDICT

9

ViewSonic XG3220
■ **HIGH DPI** Good compromise between panel size and pixel density; great contrast and colors.

■ **DOESN'T EVEN TRY** Not very bright, especially given the "HDR" pitch; mediocre pixel response.

\$590, www.viewsonic.com

SPECIFICATIONS	
Panel Size	32-inch
Native Resolution	3840x2160
Pixel Density	137.68
Panel Type	VA
Maximum Refresh	60Hz
Response	5ms
Contrast	3,000:1
Display Inputs	HDMI 2.0 x2, DisplayPort 1.2
Connectivity	USB x 3
VESA Mount	100 x 100mm
Warranty	Three years





ViewSonic

The new XG3220 is big and beautiful, but its VA panel is problematical for gaming.



Roccacat Vulcan 120

A second look at mechanical keyboard design

MECHANICAL KEYBOARDS have been a significant part of the PC gamer’s toolkit for the last seven years, and with good reason. Those simple rectangles laden with Cherry switches provide those who invest in the pricey products with a feeling unlike any that a membrane or chiclet keyboard could produce. The responsiveness and the immediate and tactile nature exuded by those switches is second to none.

Since those early days, we’ve seen refinement upon refinement. So much so that the question has to be asked: Where do you go from here? How do you stand out in such a crowded market? It’s a tough one, but Roccacat believes it may have the answer.

The German manufacturer, known for its budget-oriented headsets, mice, and keyboards, has typically not been seen at the premium frontier of PC gaming peripherals. Its keyboards, although touting some fantastic feature sets and packing a plethora of Cherry switches, often lacked the design flair and high-end material use of some of its more prestigious competitors. It always seemed to cater more toward the would-be or younger gamer, rather than someone truly serious about where they place their digits.

The Vulcan 120 stands in stark contrast to Roccacat’s traditional offerings. It’s clean, sophisticated, and far more elegant than anything we’ve seen in the past from Roccacat, and for a company that’s looking to clean up its image and lean more on that Germanic design heritage, it’s definitely a good start. The single sheet of brushed aluminum is simple and smooth, unblemished by any obtrusive gaming insignias or branding. The key switches, a custom built mechanical variant, are raised, transparent, and fully lit with the now industry standard array of RGB LEDs,

and although they haven’t come from the design houses of Cherry, they’re some of the better bespoke switches we’ve seen.

Roccacat’s Titan Tactile switches are smooth and responsive under touch, like some strange amalgamation of a Cherry MX Red and an MX Blue, all mixed in with a super-low actuation point (1.8mm versus 2mm). They’re an absolute joy to type on, every keypress cementing itself down into place firmly, with only the faintest of clicks behind it. It’s a subtle feeling—very subtle—yet still strong enough to let you know it’s there. It’s quiet, too. Well, quiet for a mechanical keyboard, at least—no louder than that gaming staple, the MX Red, that’s for sure. But it’s that immediacy and feel that we like the most, especially in game. This is all thanks to how the key switch works in conjunction with the key cap itself.

FEATHER IN ITS CAP

In short, this is all down to just how small these key caps are. At their thinnest, each of the Vulcan’s caps are just over 3mm thick, and at the fattest part of the cap they’re 6mm. Compare that to a standard cap found on a Corsair K70—7mm and 10mm respectively—and that’s a lot less overall plastic involved, which in turn means lighter caps. It doesn’t sound like much, but reducing the overall weight in the cap means you have to apply slightly more pressure on each key to activate the switch (we’re talking minuscule amounts in reality). That’s bad, right? Well, kind of. Of course, for absolute immediacy, you’re still going to want a linear switch (an MX Red, for example), but for those who are keen typists, or who don’t rely on split-nanosecond response times, this makes a big difference. Each click is more forceful,

and it sounds and feels better. The thicker caps suddenly feel dampened, there’s less tactile feedback from them, and the sound is almost muffled in comparison. It’s a small observation, but one that makes a remarkable difference in the overall feel of the Vulcan.

Ultimately, Roccacat’s Vulcan 120 is a strong addition to Roccacat’s lineup. Its uncompromising use of build materials, utilized alongside the brilliance of those key switches, makes it a keyboard to look out for, and a definite contender for anyone looking to invest in a serious piece of premium finger-punching luxury. As far as switches go, Roccacat’s Titan Tactile, for this reviewer at least, is one of the best out there right now. **—ZAK STOREY**

VERDICT
9
KICK ASS!

Roccacat Vulcan 120
GOD OF FIRE Phenomenal switches; clean design; good key caps; aluminum design; solid software.
GRAPHICS API No pass-through
\$160, www.roccat.org

SPECIFICATIONS	
Switch Type	Roccacat Titan Tactile
Form Factor	Full-size
Media Keys	Integrated
Macro Keys	6x integrated
LEDs	16.8 million colors per key
Pass-Through	None
Dimensions	18.1 x 6.3 x 1.2 inches

Corsair Carbide 275R

A no-fuss, some-frills mid-tower

CORSAIR HAS LONG been a purveyor of understated and refined PC cases. The manufacturer's current lineup might have a few concessions to current trends higher up the pricing hierarchy, such as gaudy RGB fans and trim, but this model exemplifies its simple yet elegant aesthetic. In other words: We like how it looks.

This is a mid-priced mid-tower case that doesn't feel middle of the road. The most notable nod to luxury comes with the tempered glass panel, and while these are increasingly becoming the norm, they're not all set flush with the case itself, as this one is. However, we did run into some trouble with the rubber stays when we removed the panel—they're extremely prone to popping out of their holes, and running off for a game of hide and seek.

The air of visual restraint continues on the front panel, which is simply a solid block of color—white in our sample. The paint finish and construction material of this front panel give away the Carbide 275R's mid-tier pricing, although only slightly. From a distance, it appears to be brushed aluminum, but getting up close and tactile reveals it to be a faintly disappointing plastic with a coarse paint job. However, the overall effect is pleasing. All the controls and inputs are placed unobtrusively at the top-front, accessible without breaking the clean lines.

At the top is a magnetized dust filter, which again fits more snugly to the case than several other models we've tested from rival manufacturers, and although we're not fully sold with this design versus a more substantial pull-out or pop-out panel (as with Corsair's older case models), the execution's undeniably neat.

It feels like a smaller case to build in than some other mid-towers we've had through the doors recently, and there's not a whole lot of wiggle room when fitting a full-sized motherboard. However, it's not so tight that getting screwdrivers (and clumsy hands) in above the screw holes becomes a problem. It's compact, not cramped. There

are mounts for four 2.5-inch drives behind the mobo mounting plate, along with two drawers for bigger 3.5-inch drives side by side with the PSU enclosure along the base. Realistically, this should be enough for most builders, and keeping SSD storage on the underside helps with cable management. In fact, keeping your wires disciplined is remarkably easy throughout, a by-product of the compact layout and intelligent cable-through points.

Overclockers won't be drawn to this one, however, as it doesn't place airflow at the very top of its priorities. One 120mm fan at the front and another at the rear will keep air circulating while compartmentalizing the hot PSU for optimum airflow across your components, and that'll do the job for most enthusiasts. But if you're running a jacked setup, and live in a hot climate, consider something with an airier design and more fans out of the box. You could fit a 240mm radiator on the top and a massive 360mm radiator at the front, but it doesn't feel like it was intended for that kind of setup, because the front panel only takes air in from the extreme top and bottom.

What we have, then, is a straightforward case with easily one of the most attractive aesthetics to our eye at the sub-\$100 price point, and one that's easy to build a neat rig inside. That's a lot to like. **—PHIL IWANIUK**



Corsair Carbide 275R

SMOOTH SAILING Beautifully minimal; plenty of storage space; easy cable management.

CHOPPY WATERS Not really intended for serious overclockers.

\$80, www.corsair.com

SPECIFICATIONS

Form Factor	Mid-tower
Motherboard Support	ATX, mATX, Mini-ITX
Colors Available	White, black
Window Available	Yes
3.5-Inch Support	x2
2.5-Inch Support	x4
Radiator Support	360mm front, 240mm roof, 120mm rear
Fan Support	3x 120mm front, 2x 140mm roof, 1x 120mm rear
Dimensions	10 x 8.9 x 18.1 inches
Graphics Card Clearance	14.5 inches
CPU Cooler Clearance	6.7 inches
Weight	16lb



Characters may react badly to Reid at first, but can often help him out.

I, I mean you no harm.

Vampyr

If it's blood you want, you can count on Dr. Reid

MISTY OLD LONDON is a fine setting for a videogame. Even better if it's one about monsters hiding in the derelict wharves and foggy back streets. Better still if you're the monster doing the hiding.

You don't have to be a monster, although *Vampyr* goads you into becoming one, pointing out how much easier the game would be if you ripped into the throats of every innocent bystander you find with their back turned at the end of an alley, with no one around to raise the alarm. You could feed on rats to satisfy your bloodlust, even though they don't grant as much XP to put toward greater vampiric powers, and it's an option you may well take as the atmospheric setting would be nothing without a reluctant anti-hero, and Dr. Jonathan Reid doesn't want to be this way at all.

He awakens to his new undead state gums-deep in his own sister, an awkward situation made worse by his confusion and weakness. From then on, things get complicated. As a doctor, Reid has taken certain oaths, including one to do no harm. Balancing this against the urge to level-up your skills and unlock that extra combat move by killing indiscriminately, or to get a promised "better" ending to the game, and

avoid attracting vampire hunters to the area by being a friendlier bloodsucker, is one of the more interesting game premises of this year. You can make things worse—or better, depending on your level of crazed thirst—by using your medical skills to heal victims of illnesses before closely inspecting their carotid. They taste better this way.

The basic plot follows Reid in his attempt to find the creature that did this to him, but the meat of the game is in the side stories, talking to everyone, rummaging through their homes to find secrets, and using vampiric powers to watch them go about their unlawful business. Their lives are interesting if you just want to watch, and you can choose to thin the herd by taking away one or two genuinely despicable individuals, rather than a full-on killing spree. Later, when the devs use warring vampire clans to provide more of a combat challenge, it's less interesting. A shame, as the *Life is Strange* developer had shown a keen eye for detail in its character portraits.

The flip side is combat, a well-featured system, with combos, melee weapons lying around, and firearms and vampire powers that can be upgraded, but you rarely get anything interesting to fight. Oddly, lives

taken in combat, rather than with neck-romancing, don't count toward your kill total. Fights can often be avoided, but the vampire hunters seem infinite, and bosses are a pain if you've avoided killing, and therefore haven't had many upgrade points.

Vampyr is so close to being special. It's got the setting, the conflicted protagonist, hints of a larger conspiracy, and Dontnod's brand of *je ne sais quoi* that rendered *Remember Me* interesting and dull in equal measure. It follows in the footsteps of that title by almost seeming like two games—a fine exploration and investigation game bolted to a shonky scrolling beat-'em-up. If only the former had been better fleshed out at the expense of the latter. —IAN EVENDEN



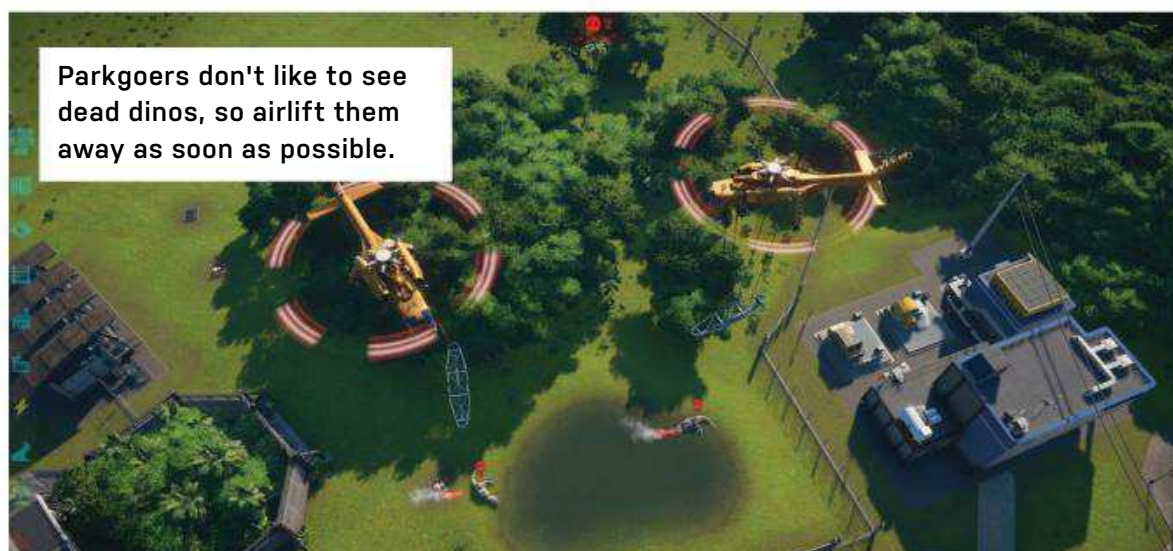
Vampyr

VAMP Atmospheric setting; interesting characters; many vampire powers.

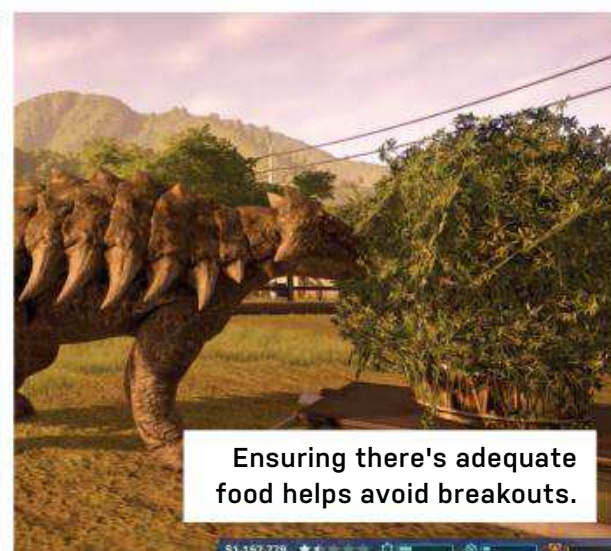
TRAMP Poor combat; color scheme defaults to gray/brown splashed with red.

RECOMMENDED SPECS i7-3930K/Ryzen 5 1600; 16GB RAM; GTX 970/R9 390.

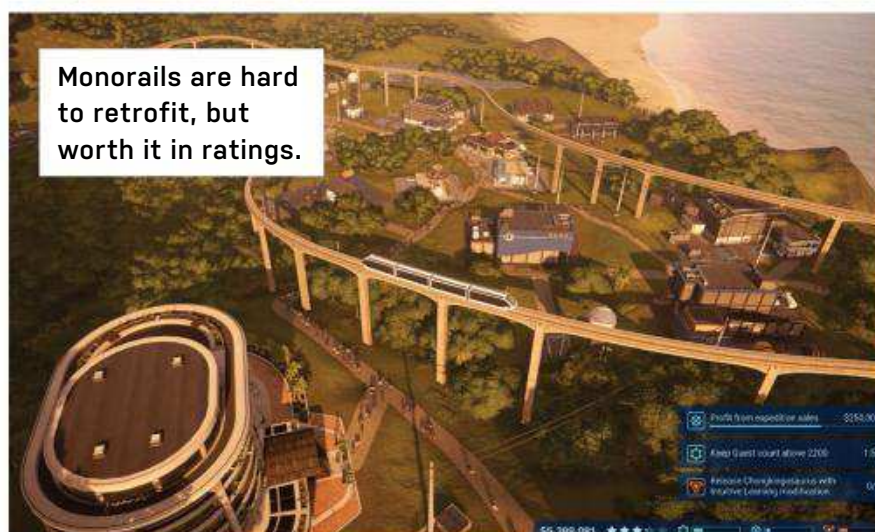
\$60, www.vampyr-game.com, ESRB: M



Parkgoers don't like to see dead dinos, so airlift them away as soon as possible.



Ensuring there's adequate food helps avoid breakouts.



Monorails are hard to retrofit, but worth it in ratings.



If you put the wrong species together, they fight.

Jurassic World Evolution

An adventure literally several years in the making

THE QUESTION OF WHETHER it's right for man to recreate dinosaurs, put by Jeff Goldblum in the 1993 movie that started the franchise off, has fallen by the wayside. Dinosaurs are here, it's almost normal now, and people spend vast amounts of money to travel to South America to see them.

As a management sim, *Jurassic World Evolution* gives you the Muertes archipelago as your playground—four parks in various states of disrepair, and a sandbox island to do what you wish on. The starting island is straightforward, and a three-star rating is enough to unlock the next, a notoriously windswept island on which some fool forgot to build any storm defenses.

Getting four stars on the first island unlocks the sandbox, but to get this—and the sandbox, Isla Nublar, the setting for that first movie, is where you really want to be—you need to play the other islands, as all your research and unlocks, though not your bank account, carry over. Unlock stuff on later islands, take it back to the start, improve the rating, get more unlocks. It's a clever loop that keeps you going in a game that unfortunately feels like a long tutorial.

There's another thing: The game is very similar to *Planet Coaster*, Frontier's 2016

rollercoaster park management game. This isn't a bad thing, as the familiarity of the system blends with the familiarity of the license to make you feel at home. And *Planet Coaster* was very good—if you're going to imitate, imitate the best. But *Evolution* feels less complex, much of the customization having been stripped out.

What you can customize are the 40-odd dinosaurs. By researching their genomes and patching in bits from other animals via your expedition and research centers—of which you can have one per map, but which combine to unlock more fruitful fossil dig sites—you build up a fearsome array of genetic modifications that make your dinos more... fearsome. There's no docility gene taken from, say, turtles, but things such as enhanced cleverness and harder claws. Advisors—some of which are voiced by movie actors, and some by people doing impersonations of movie actors—egg you on to create more dangerous specimens.

They're going to get loose. If you've seen the movies, you know that always happens. And when you're making \$400,000 a minute, you don't want anything to affect profits. Emergency infrastructure is available, and the visitors—all adults; probably don't want

to show kids getting eaten—are a forgiving lot, heading to the gift shops after exiting the shelters, rather than running for home. Escapees aren't the only problem: Harsh weather and saboteurs mean running the park is rarely a low-pressure occupation.

The game's roots in *Planet Coaster* mean it's a smooth overall experience, although it inherits an obsession with paths, an over-complicated electrical system, and awkward building placement. A reliable developer tied to a fantastic license should have produced a game with more sparks than this. While the dinosaurs wow on first contact, and there's enough content to keep an aspiring park manager busy for weeks, the game dissolves into management busywork too easily. —IAN EVENDEN

VERDICT
8

Jurassic World Evolution
RAPTURE Excellent dinosaurs; thrilling escapes; huge profits to be made each minute.
RAPTOR You get bogged down in minutiae.
RECOMMENDED SPECS i7-4770/FX-8350; 12GB RAM; GTX 1060/RX 480.
 \$55, www.jurassicworlddevolution.com, ESRB: T



LAB NOTES

JARRED WALTON, SENIOR EDITOR



Preparing for the Next-Gen GPUs

Nvidia's next GPU architecture is likely coming in August

FALL IS FAST APPROACHING, and we should see new GPUs from Nvidia in the near future. The company has been tight-lipped as usual, but I do know a few things, and can make some reasonable guesses at the rest. Code-named Turing, the GTX 1180 (possibly 2080) will be the first commercial use of GDDR6, and it will be manufactured on TSMC's 12nm FinFET process. Nvidia has big plans for Gamescom, which means hardware should be in our hands shortly before you read this.

Nvidia looks set to transition to a split architecture this round. Pascal had professional features, such as half-speed FP64 and HBM2, on certain chips (GP100 versus GP104, for example), and it looks like Volta will be exclusively the domain of supercomputing and professional solutions. Turing will likely skip the Tensor cores and have 1/32-speed FP64, but the double-

speed FP16 should be present. GDDR6 will move from 11GT/s for the 1080 Ti to 14–18GT/s for Turing, probably 16GT/s, for a nearly 50 percent generational increase in bandwidth.

I'm looking forward to seeing a single graphics card that can break 60fps at 4K ultra settings in most games. Now that 4K 120Hz displays are available, the need for faster graphics cards is more pressing than ever. If the 1180 follows past patterns, it will be 20–35 percent faster than the 1080 Ti, which means games where the 1080 Ti comes up a bit short should finally move over the 60fps barrier—or I can just drop



Whatever the next GeForce is called, it will be fast.

settings a notch, and hit 90–120fps for ultra-smooth high-res gaming. I can't wait!

As for AMD, Vega 7nm should arrive by the end of 2018, but will it be for gamers? I hope so, as there's nothing else on the roadmaps.



ZAK STOREY

Deputy editor

My processor of choice right now is the Ryzen 7 2700. Or, what I should say is very specifically our 2700. This thing is a beast—all eight cores of its 12nm form overclock like a king, and it really gives me the wiggle room I need to tinker around with it. I've managed a max overclock of 4.3GHz out of it, netting near 185 points in Cinebench's single-

core test. For me, at least, it's an incredible slice of silicon.

But I've got a problem: its platform. I'm frustrated by the lack of premium motherboards on the red side of the field. I'm a mobo man, and I need one with an extensive feature set, rear I/O, and an easy-to-use and in-depth BIOS—more importantly, it needs to look killer. Asus is

the closest manufacturer to hit the nail on the head for all four of those factors, but its AMD offerings look lackluster.

Look at Intel, and you have the Code, the Apex, and the Formula. Three super-high-end mobos. Sure, they come at a cost, but there's no denying how incredible they are. Switch to AMD, and you're left with the

X470 Hero or X370 Extreme. Neither of which is jaw-dropping.

This leaves me in a sticky position: Go with the core I love and sacrifice the aesthetic side of things—arguably one of the more important factors for me—or sack it off, do more work delidding an 8700K, and live with two fewer cores. And then I reviewed the Core i7-8086K....

Editors' Picks: Digital Discoveries

Bo Moore, hardware lead, and Alan Dexter, executive editor, reveal the tech that's been getting them excited



ECHOGEAR DUAL MONITOR DESK MOUNT

I recently redid my home office setup, part of which included a new PC build (a lovely glowing setup, thanks to three LED strips, a handful of RGB fans, and a nice clear viewing panel), as well as the introduction of a second monitor. I've been using two monitors on my office PC for a while, but I decided it was time to step up my at-home situation as well.

My main problem was that my desk at home is not terribly big, so the prospect of fitting two 27-inch monitors on there (I know, I'm spoiled) did not sound easy. To save space on the desktop, I installed this two-arm desk mount from Echogear to hold my monitors. It has gas-powered springs to make adjustments easy—I don't need a tool for anything, unless I want to tighten the adjustment tension. And to keep my desk clean, there are little channels in the bottom for me to feed cords through.

I'm a big fan of the new setup. My desk is clear and I can adjust everything as needed for maximum comfort throughout the day. More importantly, my cats are pleased with the new addition. With all that desk space freed up, there's plenty of room for them to nap next to my mouse and keyboard.

\$199, www.echogear.com



SENNHEISER HD 650

I have broken my Sennheiser Momentum headphones. They have suffered numerous yanks, drops, smashes, and other careless moments over the years, but kept soldiering on regardless. Until now. This month, I forgot I was wearing them as I walked away from the machine to go and sort something out. From that point on, I was limited to audio in the left ear only. Wiggling the wire briefly brought stereo back, but this merely confirmed my worst fears—I'd broken a trusty friend that has been with me for over two and a half years.

This is *Maximum PC*, though, and a new set of cans is never far away. Zak rooted through the gear cupboard and handed over the Sennheiser HD 650. Consider this day one of a long-term test. Initial impressions are that they're a bit tight on my head, but comfortable enough. The fact that they have detachable cables means hopefully I won't damage them in the way I did their predecessors. The sound quality is impressive, and as these are open-backed, I can hear my colleagues—an improvement over the Momentums (at least for the office).

The real takeaway, of course, is that I need to show more care around my headphones. Or wireless may be a better idea....

\$500, <https://en-us.sennheiser.com>



1More Triple-Driver In-Ears

I THINK WE ALL KNOW I'm an audio fanatic. When it comes to bouncy air vibrations rumbling my lobes, I can't get enough of the stuff. I listened to 73,520 minutes of music on Spotify last year—the equivalent of 51 days. And that's not including the countless hours spent on YouTube and the like. Having decent headphones is vital to me (and a theme in this month's "Lab Notes," apparently).

At home, I'm running with a pair of Beyerdynamic DT 1770 Pros. However, for my day-to-day activities, particularly when in the gym or commuting, I prefer something more discreet and, most importantly, disposable. Sennheiser's MX 365s are my earbuds of choice. They fit my ears well, and the bass and treble are well balanced. They're also only \$15, so I don't mind breaking or losing them.

When our own Alex Cox gushed over the 1More triple-driver over-ear headphones a few issues back, I was keen to try their in-ear equivalents. At \$100, they're hardly cheap, but boy do they come with the accessories. There are eight sets of different sized buds, two types of cable, one airplane adapter, a leather carry case, and an awesome pair of headphones. I can't say that the triple-driver design has a huge impact, but the sound quality is well balanced and exceptionally crisp on the high end. I'd prefer there to be a touch more bass, but that's just me, and they do produce a very enjoyable reference soundstage, which is to be commended. **—ZS**

\$100, <https://usa.1more.com>

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Forgotten Power > Password Picks > Threadripper Gaming

Editorial Standards

The headline for Zak Storey's column is offensive to me and, I have no doubt, to other readers. Who on your staff believes it appropriate to print such a coarse expression? Once you identify them, ask them if they believe such language enhances or cheapens the reputation of your publication. Might they believe that one's choice of words makes no difference? I am disappointed you allowed this. Please reconsider your editorial standards if this language is considered as meeting the current ones.

—Walter O'Briant

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: I apologize unreservedly for the title in question, and the offense caused. You're right, it absolutely does not live up to the editorial standards we hold ourselves to, and I promise that this will not happen again.

Graphical Grunt

I built a machine way back in early January 2015, and went with a Radeon RX-295X2 GPU, which cost under \$800 at the time. I've



The RX-295X2: A great card, but those dual GPUs are power-hungry.

heard relatively little about this card even though, looking at the performance of the latest GPUs, its numbers are holding up quite well. It's in Tom's Hardware's second tier of its comparison metrics, and by raw processing power, it's still beating the GTX 1080i and Titan XP—you have to go to the Titan V to better its numbers, and it's blown away, of course (based on numbers from Wikipedia's GPU charts). I'm not a gamer, and I know its gaming performance didn't match up nearly as well, but still, why has this card received so little attention, or even mentions?

—Robert Stepan

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: The Radeon RX-295X2 was, and still is, a bit of an oddity

because it uses two GPUs on a single PCB, and peppers that with some esoteric liquid cooling. Originally launched in 2014, it did well in reviews at the time (we gave it our Kick Ass award), although with the caveat that it relies on CrossFire to make sure the two GPUs work well together (and some games don't play well with CrossFire, or it gets patched in later on). At launch, it had a list price of \$1,500, which was a bit steep, to be honest, but if you managed to pick yours up for half that, then that's a great deal. The fact that it's still competitive four years on is to be commended. The one thing we would say is that, yes, it'll trade blows with a GeForce GTX 1080 even now, but the newer GPU draws just 180W, as opposed the 500W that you'll

need for the dual GPUs of the RX-295X2, and that means higher electricity bills—even so, it's still an incredible card.

Power Play

A 1,500W power supply should not be tripping circuit breakers, unless it is defective. I have two 1,200W, 850W, and 900W machines on the same circuit, and it does not trip the breaker. Since you are in a new building, did you have a licensed electrician check the wiring? If it is the wiring, it should be upgraded immediately, as it's a potential fire hazard. Did you check the voltages on the 24-pin connector on the power supply? The two main conditions that will trip breakers are shorts and overloads. Weedy extension cables? What is the gauge on the cables?

—Ron Apra

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: I have since checked, and the wiring in the building is absolutely fine, which would indeed indicate that something has gone awry with the PSU. To be honest, we weren't totally convinced that it was the cabling at the

submit your questions to: comments@maximumpc.com

time, but couldn't for the life of us work out what was happening, and given that it was a new building, decided that it must be the cabling at fault (we've experienced some truly horrific cabling in the past). It's looking very likely that the power supply must have been shorting somewhere, but either way, we managed to sort out the problems with our upgraded build, and haven't had any problems since. The PSU was passed on to our IT department to be recycled, so all good in the end.

Password Pro

One thing Roboform does that LastPass lacks is the ability to work while using Firefox Private browsing.

—Daniel Thigpen

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: I didn't know that Roboform could do that, and that's potentially useful for some of our readers, so I'm happy to pass your recommendation on. We've had a lot of responses about our LastPass recommendation, so we'll take a look at this again in a future issue.

Easy Split-Toning

Nice article on "Creating a Split-Toning Effect in Photoshop" (June 2018), but why do it the hard way? Try this: First select "Mode → Grayscale," then "Mode → Duotone," pick one of the many presets, alter it if you wish, or make a custom one, and you're done. If you want to complicate it, you can first go to "Adjustments → Black and White," and adjust the Lightness values for various colors in the original to tweak the tones in the Grayscale conversion. Then apply the steps previously mentioned. Easy peasy.

—W. B. Vaughan

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: Part of the reason for doing the tutorials the way

we do is to show you a structured process for getting a desired effect, with the potential for you to experiment as you go. There are sometimes quicker ways of achieving the same effect, and in the case of split-toning, there are several ways of doing just that, and your suggestions give plenty of scope for experimentation, too, so thank you for your idea.

Piping to Bash

I found the article about installing Pi-hole on a Raspberry Pi interesting. Since I have a RPi and I'm allergic to advertising, I wanted to give it a try. The further I progressed, the more the phrase "installation via this method carries a risk" slowly rose to the surface.

I did go to the Pi-hole site for answers. When I click "Review the code," I get a list of some 20 files. I'm hardware... I didn't know what to look at. Could I impose on your good nature to explain "piping to bash" a little further, or better yet, offer alternate Pi-hole installation methods? I didn't find it with Synaptic.

—Steve G

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: Piping to bash is basically a way of running a script, as you pass the output from an operation to the shell (the bash). There's only a risk in piping to bash if you don't know what that script does, in the same way that you're potentially opening yourself to risk when you install something in Windows. It all comes down to trust, and if you trust the source, then you generally shouldn't have anything to worry about, although there are fears of man-in-the-middle attacks. When it comes to the specifics of the Pi-hole installation, we've verified the installation script at the time of writing, and it's fine to run it, although if

it's been updated since, we can't 100 percent guarantee it still is—you should be fine, though, as it's from a trustworthy source.

Not Looking Up

Additional comment on the "No Lookup" letter in the June 2018 issue: Using IP rather than DNS will make SSL certificates fail to validate on secure sites. With more and more moving to HTTPS (and eventually IPv6), using IPs only is in the past.

—Dan Parker

EXECUTIVE EDITOR, ALAN DEXTER, RESPONDS: That's also a very good point, succinctly put, Dan.

Threadripper Tripping

I have been a reader of your magazine for years now, and pretty much make all of my PC hardware buying decisions per your recommendations. However, for the first time, I regret a purchase: the Threadripper 1950 for my new build. (Threadripper is recommended in your Turbo reference build.) The performance of the Threadripper is not at all convincing in games—I am playing at the monitor's native resolution of 3440x1440. Specifically, *Assassin's Creed Origin* benchmarks and gameplay with the Threadripper and a 1080Ti made me stop playing the game—averaging 30–40fps, with two settings lower than the GeForce optimal. I've spoken to both Ubisoft and AMD helpdesks about this, and both are pointing fingers at each other after exploring all possible scenarios of driver uninstall, antivirus issues, and so on.

In the 10 years I have been into high-end gaming, this never happened to me with any of the Intel processors. I understand this might be a great processor in other applications, but disabling half of the cores just to get somewhat reasonable

frames in the likes of *Far Cry 5* and so on is not really a convincing argument to buy this over an Intel CPU. In summary, I would not at all recommend buying this CPU, and I am keen to hear your view and experience with games in combination with this processor.

—Alex Seile

DEPUTY EDITOR, ZAK STOREY, RESPONDS: Hmm, this is a curious one. It's true that Intel has a slight edge on AMD right now in terms of performance in game, but this has mostly been down to single-core IPC performance and game optimization more than anything else. Because of that, Threadripper is, in some cases, three to four frames slower than its Intel counterparts when it comes to average fps. As a whole, we recommend the Turbo build not necessarily as a gaming-specific machine, but more a pro workstation, designed to maximize your performance in professional workloads, as well as being a hotshot at any task you throw at it.

That said, I'm currently running a Threadripper 1950X alongside a GTX 1080 Ti, so I've been able to do some testing. Your superwide resolution of 3440x1440 is roughly 5 million pixels, while the standard 2560x1440 resolution is 3.7 million, and 3840x2160 (4K) comes in at 8.3 million total pixels to push each second. In *Assassin's Creed Origins*, on the Ultra preset at 4K, I managed an average frame rate of 48fps. Go down to 2560x1440, and I averaged 76fps—3440x1440 should be somewhere in the middle of that, so there's definitely an issue with your system. If I were a betting man, I'd put my money on there being a conflict between your operating system and your drivers. It might be worth flattening the entire thing, and reinstalling your OS from scratch. 🔌

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THE BUILDS

BUDGET



MID-RANGE



INGREDIENTS

PART		PRICE
Case	BitFenix Nova TG	\$51
PSU	450W Corsair CX450	\$45
Mobo	ASRock AB320M-HDV	\$50
CPU	AMD Ryzen 5 2400G	\$160
GPU	N/A	\$0
RAM	8GB (2x4GB) Team T-Force Dark @ 3,000MT/s NEW	\$80
SSD	120GB Kingston A400 120GB 2.5 SSD NEW	\$35
HDD	1TB Seagate Desktop ST1000DM003 NEW	\$37
OS	Ubuntu Desktop Linux 18.04 LTS 64-bit	\$16

Approximate Price: \$474

CHECK IT OUT! A \$474 price point. We've done it—we've dragged the budget build's sorry backside down into the realm of sub-\$500 affordability again. And it's about time. The memory and GPU crisis of 2017 and early 2018 is finally abating in what can only be described as an over-saturation of the market. Thank you, ASIC miners/cryptocrash. So, what's changed this time around? How did we hit it? Well, the Nova TG is back in stock and at affordable levels at \$51, instead of the \$91 from last issue, we've decided to opt for an ever-so-slightly slower 8GB memory kit, which saved us a fair chunk, and then did a few switcheroos with our storage, just to keep meeting those price targets. What you're left with is a system coming in at \$474, which is pretty darn awesome, if we do say so. Ideal for light desktop work, Internet browsing, and mid-range integrated 1080p gaming. There's even room to throw in a better GPU in the future, too.

INGREDIENTS

PART		PRICE
Case	Fractal Design Meshify C	\$74
PSU	550W EVGA SuperNOVA 550 G3 80+ Gold	\$80
Mobo	MSI Z370 Tomahawk	\$140
CPU	Intel Core i5-8400	\$180
Cooler	Be Quiet! Dark Rock 4	\$75
GPU	Gigabyte GeForce GTX 1060 3GB NEW	\$240
RAM	16GB (2x8GB) G.Skill Ripjaws V Series 2,666MT/s NEW	\$150
SSD	250GB Samsung 970 Evo M.2 PCIe SSD	\$108
HDD	Hitachi Deskstar E7K1000 1TB 7,200rpm	\$37
OS	Windows 10 Home 64-bit OEM	\$100

Approximate Price: \$1,184

SADLY, WE COULDN'T also achieve a price decrease in our mid-range build. That said, we're more than happy with how this build is spec'd out. The Core i5-8400, paired with 16GB of memory and a 250GB PCIe SSD, is a punchy combo. Couple that with the GTX 1060 3GB, and you're looking at a system that can do everything from amateur videography, thanks to Adobe and Intel's latest iGPU upgrade to Premiere, to pumping most, if not all, of the latest titles at 1080p 60fps no sweat. You could save some cash by dumping the MSI Tomahawk in favor of something cheaper, but with its solid connectivity, decent BIOS, and aesthetic appeal, we just couldn't part with it this time around. The PCIe SSD, although great for productivity, is also perhaps a touch overkill. Replacing it with a 250GB Samsung 860 Pro, or another standard 2.5-inch SSD, could save you half the cost. That combo alone would be enough to drag this build down to the \$1,000 mark.



UPGRADE OF THE MONTH



NOCTUA NT-H1
THERMAL COMPOUND

This is by far one of the slowest times of the year for hardware releases. At the end of the financial year, the vast majority of companies enter what’s known as a “quiet” period. At least, they do in the tech industry. What this means is no new tech releases until the next year. We’ve had Computex and CES, with various manufacturers showing off their latest prototypes, and that’s it—now we play the waiting game. Although that means we don’t have lots of things to talk about, it does mean we can focus on the little things. And for us, thermal paste is one of those little things that can make a big difference. There’s only one brand we go to for the goopy stuff, and that’s Noctua. Its NT-H1 is the perfect consistency. It’s not runny, it spreads well, transfers heat as well as any other paste we’ve tested, is affordable, and, more importantly, is non-conductive, so even if we get overspill, there’s limited chance of it frying anything. **\$6, <http://noctua.at>**

WE RECENTLY RECEIVED a reader’s letter surrounding potential problems with his Threadripper rig being a little sluggish in games. Although there’s more to that issue than meets the eye, we thought it’d be a good opportunity to respect the turbo build to Team Blue, to provide you with some choice. After all, there’s no denying that Intel’s got the gaming aspect shored up with all of its processor series right now. Whether that’s because of the impressive single-core performance, or thanks to its architectures remaining relatively unchanged over the last nine years, or a bit of both, Intel parts are very much dominant.

But let’s get this straight: For the cash, you do lose out on multicore performance. The Intel Core i9-7900X we’ve chosen for this build touts 10 cores and 20 threads. An impressive number, for sure, but compared to the 16 cores found on the Threadripper alternative, at \$50 less, it does miss the mark a touch. On the plus side, when it comes to motherboard selections and memory choice, it opens the field up significantly. There’s no denying there’s a lot more options for Intel than there is for AMD, and a far wider range of prices, too. You can even get an X299 board for as low as \$160 in some places.

On top of our major platform change, we’ve dropped our meme-level love of NZXT’s Kraken X72 for Corsair’s Hydro H150i Pro 360mm AIO instead. It’s an AIO we’ve been using day in and day out on our test bench for the last three months or so, and it’s an absolute kicker.

For more of our component recommendations, visit www.maximumpc.com/best-of-the-best

INGREDIENTS

PART		PRICE
Case	NZXT H700i	\$180
PSU	Corsair RM750X Modular Gold	\$110
Mobo	ASRock X299 Extreme4	NEW \$179
CPU	Intel Core i9-7900X	NEW \$900
Cooler	Corsair Hydro H150i Pro 360mm AIO	NEW \$160
GPU	Zotac GeForce GTX 1080 Ti 11GB	NEW \$720
RAM	32GB (4x 8GB) Corsair Vengeance LED 2666	NEW \$355
SSD	512GB Samsung 970 Pro M.2 NVMe	\$250
HDD	2x 2TB Seagate BarraCuda ST2000DM006	\$118
OS	Windows 10 Home 64-bit OEM	\$100

Approximate Price: **\$3,072**

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